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EXECUTIVE SUMMARY

This report details the Large Scale Demonstration Project (LSDP) conducted at Argonne National Laboratory-East's (ANL-E) Chicago Pile-5 (CP-5) Research Reactor. The LSDP was conducted at ANL-E during the period of July 1996 to January 1998 to evaluate selected decontamination and decommissioning (D&D) technologies. In addition, the LSDP provided a unique management experience in the form of the Strategic Alliance for Environmental Restoration (SA).

The primary products of the CP-5 LSDP were the Innovative Technology Summary Reports (ITSRs), which provided performance and cost information on technology demonstrations. This final report provides a historical summary of the work performed, addresses lessons learned, and provides summary level information to assist the technology user in identifying candidate innovative technologies. Candidate technologies should then be thoroughly evaluated through a detailed review of the ITSRs.

The SA chose D&D technologies in the areas of characterization, decontamination, dismantlement, and worker health and safety. These technologies were then demonstrated and compared against the current baseline technologies in the areas of performance, application, and cost. In most cases, these improved and innovative technologies provided a higher degree of worker protection and comfort, a decrease in activity duration, lower costs, more efficient operation, and lower waste volumes.

The technology demonstrations provided benefits to problem holders, technology developers/providers, stakeholders and member organizations. These benefits included:

- By identifying and validating new and improved and innovative technologies, the stakeholders now have the tools to reduce cost, schedule and total dose during performance of D&D activities.
- The project provided an opportunity to technology developers/providers for validating their technologies through an ongoing D&D activity.
- The project provided problem holders with appropriate data for selection, evaluation and use of D&D technologies.
- Participants were allowed the opportunity to gain valuable experience in the emerging D&D industry.

As a direct result of successful demonstrations, technologies have been deployed in both commercial and government D&D applications. Examples are as follows:

- Centrifugal Shot Blast was implemented by Babcock &Wilcox for 30,000 ft^2, ¼-inch concrete removal at B&W's plant in Pittsburgh.
- The Portable X-Ray Fluorescence Spectrometer is routinely being used at ANL-E for hazardous materials analysis during characterization and facility assessments.
- The In Situ Object Counting System and SRA Surface Contamination Monitor were used at ANL-E to assist in characterization of Building 301 Hot Cells.
- An alternate application of the SRA Surface Contamination Monitor was identified and demonstrated as part of Hanford C Reactor LSDP.
- Pipe Explorer™ was used for characterization of below grade piping at ANL-E due to the success of the LSDP demonstration.
- SA members and other companies have included CP-5 demonstrated technologies in proposals for upcoming work.
- Future potential applications have been identified at ANL-E for many of the technologies.

The SA combined members' expertise in management and D&D from commercial

utilities, academia, national laboratory, technology companies and the Department of Energy (DOE), ensure the highest benefit to the D&D industry from the technology evaluations. Utilizing the Internet and Web pages, the LSDP was successfully managed by SA members at various locations across the United States. Additionally, this provided an effective way to relay the information learned from the demonstration to the interested public.

The results for each demonstration were reported with a one page Technology Demonstration Summary Sheet, a Technology Technical Data Report, and an Innovative Technology Summary Report.

Additional means for information exchange of the LSDP findings were forums and conference attendance. Through papers prepared and presented at American Nuclear Society meetings, two open houses at CP-5, various nuclear forums, annual waste management conferences, and a technical information exchange, to name a few, the knowledge and experience gained through the LSDP was provided to interested members throughout the nuclear industry.

In summary, the LSDP provided an efficient and effective means of demonstrating and facilitating deployment of innovative technologies to the D&D industry. The specific technology selection and application will dictate the potential D&D cost reductions for stakeholders.

ACRONYMS

AA	Alliance Administrator
AC	Alternating Current
ALARA	As Low As Reasonably Achievable
amp	Ampere
ANL-E	Argonne National Laboratory-East
ARMS	Advanced Recyclable Media System
BEMR	Baseline Environmental Management Report
CBD	Commerce Business Daily
cfm	cubic feet per minute
Co	Cobalt
ComEd	Commonwealth Edison
CP-5	Chicago Pile-5
Cs	Cesium
D&D	Decontamination & Decommissioning
DAWP	Dual Arm Work Platform
DDFA	Deactivation and Decommissioning Focus Area
DE&S	Duke Engineering & Services, Inc.
DOE	Department of Energy
DOE-CH	Department of Energy - Chicago Office
DOE-EM	Department of Energy - Environmental Management
DOP	di-octyl phthalate
EM	Environmental Management Office
EM-30	Environmental Management Office of Waste Management
EM-40	Environmental Management Office of Environmental Restoration
EM-50	Environmental Management Office of Science and Technology
EM-60	Environmental Management Office of Nuclear Materials and Facility Stabilization
EPRI	Electric Power Research Institute
FETC	Federal Energy Technology Center
FIU	Florida International University
ft	feet
G-M	Geiger-Mueller
GNET	Global Network of Environmental Technologies
gpm	gallons per minute
HEPA	High Efficiency Particulate Air
Hz	Hertz
IC	Integrating Contractor
ICF	ICF International
in	inch
ISOCS	In Situ Object Counting System
ITSR	Innovative Technology Summary Report
lbs	Pounds
LCD	Liquid Crystal Display
LLRW	Low-Level Radioactive Waste
LSDP	Large Scale Demonstration Project
m^3	cubic meters

MACS	Mobile Automated Characterization System
MDA	Minimum Detectable Activity
ml	milliliter
NIOSH	National Institute of Occupational Safety and Health
ORNL	Oak Ridge National Laboratory
OST	Office of Science and Technology
PC	Personal Computer
pCi	picoCuries
PCRS	Pegasus Coating Removal System
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
psi	pounds per square inch
R&D	Research and Development
RFP	Request for Proposal
RFQ	Request for Quote
RTDP	Robotics Technology Development Program
S&M	Surveillance and Maintenance
SA	Strategic Alliance for Environmental Restoration
SCM	Surface Contamination Monitor
SIMS	Survey Information Management System
Sr	Strontium
SRA	Shonka Research Associates
STCG	Site Technology Coordination Groups
Tc	Technicium
TD	Technology Development
TIE	Technical Information Exchange
TSC	Technology Selection Committee
TSC-L	Technology Selection Committee Lead
TTDP	Technology Technical Data Packages
USACE	U.S. Army Corps of Engineers
VAC	Volts Alternating Current
Web	World Wide Web
XRF	X-ray Fluorescence Spectrometer
3M	Minnesota Mining and Manufacturing Company

1.0 INTRODUCTION

The objective of the Large-Scale Demonstration Project (LSDP) was to select and demonstrate potentially beneficial technologies at the Argonne National Laboratory-East (ANL-E) Chicago Pile-5 (CP-5) Research Reactor. The purpose of the LSDP was to demonstrate that by using innovative and improved decontamination and decommissioning (D&D) technologies from various sources, significant benefits could be achieved compared to baseline D&D technologies. The Department of Energy's (DOE) Office of Science and Technology (OST) Deactivation and Decommissioning Focus Area (DDFA) funded the project. This area focuses on systems and capabilities that can be used in facility deactivation, ongoing surveillance and maintenance (S&M) activities and facility D&D tasks.

The primary products of the CP-5 LSDP were the Innovative Technology Summary Reports (ITSRs), which provided performance and cost information on technology demonstrations. This final report provides a historical summary of the work performed, addresses lessons learned, and provides summary level information to assist the technology user in identifying candidate innovative technologies. Candidate technologies should then be thoroughly evaluated through a detailed review of the ITSRs.

A Technology Selection Committee (TSC) was comprised of representatives from industry, academia and a national laboratory. The committee evaluated numerous technologies and chose those that met project standards and were applicable for demonstration at CP-5.

Demonstrations were conducted in four areas: characterization, decontamination, dismantlement, and worker health and safety. The technologies were evaluated with respect to the baseline for effectiveness and quality of results, speed and responsiveness, safety, mobilization and demobilization, support requirements, ergonomics, waste generation, readiness status, and cost.

The characterization demonstrations evaluated internal pipe and contaminated surface area characterization technologies. The pipe characterization demonstrations compared methods for characterization of embedded piping to the baseline technology of excavating, dismantling and surveying. Surface characterization techniques were compared with manual characterization using hand-held instruments, manual recording of data and the need to send samples off-site for analysis.

The decontamination technologies evaluated included coating and concrete removal methods, as well as liquid decontamination. Concrete decontamination technologies were compared with the baseline of manual mechanical scabbling, while liquid decontamination was compared with shipping the water in tanks to an on-site evaporator facility for treatment, and the use of mobile filtration treatment and selective ion exchange treatment to remove cesium and cobalt.

The dismantlement technologies demonstrated improved tools and robotics. Improved tools were compared with the unimproved model, and robotics were compared to the baseline of manual entry and use of long handle tools.

Worker health and safety compared innovative personal protective equipment with the baseline Tyvek® suit. Analysis of the coveralls examined the suits' ability to protect the worker, donning and doffing ease, fit of the suit, and waste generation. Workers evaluated heat, perspiration factors, comfort and the durability of the suit.

A one-page Technology Demonstration Summary Sheet provided a brief summary of the technology and results for each demonstration. The demonstration ITSRs provided details on the technologies, the demonstration performance and applications, cost, regulatory policies and lessons learned. The Technology Demonstration Summary Sheets and ITSRs were sent to a DOE technology end-user targeted mailing distribution.

2.0 STRATEGIC ALLIANCE OBJECTIVES

2.1 Purpose

The purpose of the CP-5 LSDP was to evaluate, select innovative "field test ready" D&D technologies, demonstrate those technologies in a large-scale demonstration environment, and compare the results against existing commercial baseline technologies. The purpose was also to show that significant benefits can be achieved through the utilization of enhanced D&D technologies, or to verify that existing baseline technology practices are the most cost-effective.

The CP-5 LSDP demonstrated D&D technologies at the ANL-E facility not only to benefit ongoing CP-5 project D&D activities, but also to benefit broader DOE and commercial sector needs. The LSDP was created to integrate technology demonstrations with management approaches to support the ongoing D&D of CP-5 funded by the Environmental Management Office of Environmental Restoration (EM-40). The Department of Energy – Chicago Office (DOE-CH) and the DDFA managed this demonstration under an alliance of nuclear, general industry, academia, technology developers and a national laboratory. This alliance selected, prioritized, demonstrated, and evaluated technologies against established project baselines. Technology performance was documented to qualify the technologies for commercialization and future use within the DOE Complex.

Four technology demonstration categories were identified as applicable for the CP-5 LSDP. These categories were:

- Characterization
- Decontamination
- Dismantlement
- Worker Health and Safety

2.2 Objectives

The objectives of the CP-5 LSDP were to:

- Demonstrate innovative and improved D&D technologies, develop performance comparisons to existing methods and technologies, and illustrate economic and worker-related benefits.
- Test technologies to achieve meaningful cost and performance information for potential end-users.
- Utilize an ongoing D&D project for technology demonstrations, in order to qualify technologies for repetitive, reliable implementation within the DOE Complex and by industry and commercial utilities.
- Operate from a position of DOE's self-interest to ensure that the LSDP at CP-5 is primarily focused on DOE Complex-wide problems.
- Maximize participation of alliance members at CP-5 to improve technology identification and repetitive transfer within the private sector, while integrating industry, university, national laboratory and international expertise to accelerate technology progress.
- Leverage funding and resources at CP-5 from federal, private sector, and other agencies to optimize resolution of the complex problems facing federal and private entities in the D&D of nuclear facilities.

To accomplish the CP-5 LSDP purpose and objectives, DOE-CH selected a management team representing industry, academia and a national laboratory, and approved the organizational structure to manage the execution of this demonstration project. The management team was referred to as the Strategic Alliance for Environmental Restoration (SA).

The implementation of the CP-5 LSDP, which fully integrated innovative technologies and management approaches, was a critical element in the DOE-Environmental Management Office's (EM) D&D objective. Due to the large number of planned D&D operations scheduled during the next 10 years, it is imperative that significant cost-reducing technologies be demonstrated and replicated across the DOE Complex. Regulatory acceptance and routine utilization of these technologies by contractors can only be assured by scientifically sound demonstrations in contaminated environments.

The world's largest environmental cleanup effort continues to be focused on the DOE Complex. The significant technical and economic concerns associated with this effort underscore the need for crucial cost-effective technologies and management approaches.

The SA, under the direction of the DOE-CH and the DDFA, conducted this demonstration project at the CP-5 Research Reactor at ANL-E. Effort was made to qualify technologies for commercialization and subsequent use within the DOE Complex and private industry.

The overall performance plan for the project was documented in the "CP-5 LSDP Project Management Plan, Rev. 0, dated March 1996".

Leadership for DOE-CH was provided by the Environmental Management Office of Science and Technology (EM-50) Program Manager, as the CP-5 D&D/LSDP DOE Manager. In this position, the D&D/LSDP DOE Manager was responsible for the successful integration of the LSDP with the ongoing D&D project. The Federal Energy Technology Center (FETC) Project Manager and DDFA Program Manager provided co-management.

The four major tasks that comprised the CP-5 LSDP were project management, technology identification and selection, technology demonstration and evaluation, and technology transfer.

2.3 Strategic Alliance Organizational Structure

To accomplish the objectives of the LSDP at CP-5, DOE-CH selected the SA, a group representing industry, academia and a national laboratory. For this particular project, Duke Engineering & Services Inc. (DE&S) was selected to serve as the Integrating Contractor (IC) for the SA. Joining DE&S in the SA were Argonne National Laboratory, Commonwealth Edison (ComEd), Florida International University (FIU), ICF International (ICF) and Minnesota Mining and Manufacturing Corporation (3M). The SA worked with DOE-CH in the common pursuit of D&D projects and initiatives to which their capabilities and experiences can be applied to address the D&D problems of the DOE Complex.

The project, funded by the EM-50 through the FETC under the DDFA, was identified by Project Number CHO-6-DD-23, Large Scale Demonstration at CP-5 (ANL-E).

Initial funding for the LSDP was facilitated through a Basic Ordering Agreement between ANL-E and DE&S. DE&S placed subcontracts with members and technology vendors as appropriate. Long-term funding was facilitated through a Cooperative Agreement between DOE-CH and the SA. DE&S acted as the contract administrator on behalf of the SA.

The CP-5 LSDP interfaced with the ANL-E Technology Development (TD) division, which was responsible for D&D of the CP-5 Research Reactor Facility. To the maximum extent possible, CP-5 D&D plans and procedures were used to facilitate and control demonstrations. The demonstrations were incorporated into the current safety and environmental envelope, minimizing start-up costs and allowing demonstrations to commence in a relatively short time frame.

2.4 Strategic Alliance Activities / Duties / Responsibilities

Strategic Alliance Board of Directors
The SA Board of Directors was responsible for facilitating corporate commitment and oversight. They were responsible for setting policy, appointing members of the Technology Selection Committee (TSC), approving budgets, approving demonstrations and reviewing and approving formal project communications. Membership was comprised of a single representative from each SA participant. The position of Chairperson was held by 3M at the outset, and was then transferred to ComEd for the remainder of the LSDP.

Project Management
Overall project management and project control activities for the SA were the responsibilities of both DE&S and ANL-E. DE&S, with SA member support, was responsible for preparing subcontracts with SA members, issuing the project management plan, conducting project review meetings, preparing status reports and technical task plans, and providing overall project direction. ANL-E was responsible for developing and maintaining the revised schedule and cost baseline for CP-5 D&D and the LSDP, and providing on-site interface with CP-5 D&D project personnel and SA support personnel.

Alliance Administrator
The Alliance Administrator (AA) was responsible for project management of the LSDP. DE&S served as the AA and was responsible for providing adequate resources and staffing to ensure that all activities carried out at the CP-5 facility conformed to the applicable requirements in facility documents, as well as to procedures produced in support of the LSDP (i.e., test plans). In addition to project management responsibilities, the AA ensured that appropriate language was included in all contracts issued to technology providers to ensure compliance with all facility safety requirements.

Technology Selection Committee
The TSC was responsible for selecting and evaluating technologies demonstrated as part of the LSDP. This committee was comprised of one representative from each member of the SA. The TSC used the criteria and methodology contained in the "Technology Selection and Demonstration Process: procedure dated January 1996" to evaluate candidate technologies and select those with a high probability for successful demonstration at the CP-5 facility. In addition to selecting the candidate technologies, the TSC was also responsible for assigning Test Engineers for demonstrations and for evaluation and assessment of the technology upon completion of the demonstration.

TSC Lead
The TSC Lead (TSC-L) provided the following functions as they related to demonstration execution and post-demonstration reporting:

- Determined the technology specifications and vendor information requirements for a proposed demonstration. These were documented and forwarded to the AA for incorporation into the Request for Quote (RFQ).
- Prepared the technology demonstration cost estimate and forwarded it to the AA for use in contract negotiations.
- Evaluated proposals received from vendors in response to the RFQ, and assisted in the selection of vendors to perform the demonstrations.
- Provided direction and guidance to Test Engineers on the expectations for the demonstrations. Reviewed all demonstration documents to ensure these expectations were being met.
- Prepared and forwarded to the AA a Technology Demonstration Summary Sheet within two weeks of the completion of a demonstration.
- Coordinated the preparation of the ITSRs for each technology category.

Test Engineer

The Test Engineer assigned by the TSC-L, who had primary responsibility for the execution of a specific proposed demonstration. Once assigned by the TSC-L, this individual:

- Determined all requirements necessary for successful completion of the demonstration. These included environmental, safety and health, and technical considerations.
- Prepared a Test Plan, including any necessary operating procedures if required, which addressed all tasks and requirements for the conduct of the demonstration.
- Reviewed the Test Plan and Hazards Analysis against the authorized safety/environmental envelope.
- Coordinated revisions or addenda to appropriate documents, which constituted the safety/environmental envelope, if, the demonstration was determined to be outside the current authorization basis.
- Provided the LSDP Safety Committee with pertinent technology selection and demonstration information, and addressed any issues or concerns raised through the committee's review.
- Coordinated and scheduled the demonstration.
- Collected performance, cost, etc. data during the technology demonstration.
- Assisted in preparation of post demonstration documentation.

Cost Analysis

The U.S. Army Corps of Engineers (USACE), under contract with the FETC, was assigned lead responsibility for collection and analysis of all cost information related to ITSR preparation by the SA. Since the USACE was not a member of the SA, it was necessary to provide an interface to ensure that the needs of the SA, which had been contracted by DOE-CH to manage the LSDP, were met. The USACE provided the following services:

- Reviewed Test Plans to determine cost collection needs.
- Provided standardized cost collection forms for incorporation into attachments to Test Plans.
- Analyzed cost information and provided the information necessary to complete the cost section of the ITSRs.
- Provided detailed cost analysis for the Technology Technical Data Report.

Benchmarking

ICF International (ICF) was designated as the coordinator for information collection as it related to cross-technology comparisons and cost data required by the USACE in support of FETC. ICF provided the following services:

- Reviewed Test Plans and provided a standardized questionnaire for each technology category.
- Forwarded Test Plans to the USACE for review.
- Provided, as attachments to Test Plans, all necessary data forms and survey sheets for information collection.
- Collected all performance data upon the completion of each demonstration, and maintained a database of appropriate information to facilitate preparation of the final report.
- Provided coordination with the USACE and information for ITSR preparation.

3.0 CP-5 BACKGROUND / HISTORY

The nuclear weapons complex in the United States began as a product of the Manhattan Project in the 1940s. Currently, the DOE Weapons Complex encompasses more than 7,000 aging and contaminated facilities, which require environmental management and deactivation. Approximately 900 contaminated buildings require decommissioning. It has been estimated that D&D costs for this effort could exceed $65 billion. Environmental discriminators within the decommissioning effort include an estimated 1 million tons of metal to be generated from future D&D efforts within DOE, greater than 23 million cubic meters of concrete within contaminated buildings, and 400,000 tons of scrap metal requiring disposition currently in scrap metal piles within the DOE Weapons Complex.

The mission of the DDFA is to develop and demonstrate improved technologies and systems to characterize, deactivate, survey and maintain, decontaminate, dismantle, and dispose or recycle DOE surplus facilities and contents. The DDFA mission includes facilitation of the acceptance, approval, transfer, commercialization, deployment, and implementation of these technologies and systems. The major drivers for the DDFA are the high safety and health risks associated with facility deactivation and Surveillance and Maintenance (S&M) using currently available baseline technologies, and mortgage reduction by lowering S&M costs and decommissioning costs.

During the early 1990s, the DOE initiated a program for research and development of new technologies to expedite the environmental restoration activities within the DOE Complex. The intent of this program was to address significant technical and economic concerns, which resulted from the past DOE weapons production and research programs.

In 1994, DOE-CH put forward a concept of joint public and private collaboration to focus on technology solutions to those environmental concerns. In response to the 1995 DOE FETC request for proposal (RFP) for “large scale demonstration projects,” DOE-CH proposed the CP-5 Research Reactor Facility, with its ongoing D&D project, as the demonstration site. The objective of the LSDP was to demonstrate that, by using innovative and improved D&D technologies from various sources, significant benefits could be achieved compared to baseline D&D technologies.

The implementation of a LSDP, which fully integrates innovative technologies and management approaches, was critical to the DOE Office of Environmental Management’s (DOE-EM) D&D mission. Due to the large volume of planned D&D operations scheduled during the next 10 years, significant cost reducing technologies must be demonstrated and deployed across the DOE Complex. In addition, regulatory acceptance and routine utilization of these technologies by contractors must be supported by scientifically sound demonstrations in contaminated environments. Since nuclear materials production and research facilities represent significant and unique D&D challenges for the DOE, the utilization of a nuclear research facility containing a reactor, hot cell, rod storage area and fuel pool as the first D&D LSDP was particularly appropriate.

After 25 years of operation coupled with 15 years of cool down, CP-5 contained significant activation and contamination levels representative of a nuclear facility; however, these levels are not so high as to cause undue safety concerns during the inevitable manual operations necessary for full-scale demonstrations. Having many of the essential features of other nuclear facilities in the DOE Complex (e.g., Savannah River Site reactors), the CP-5 facility could be utilized as a demonstration facility for the future D&D of larger, more highly contaminated nuclear facilities.

A detailed D&D baseline had been developed for the CP-5 D&D project and numerous non-nuclear system components had been removed prior to the LSDP. The baseline provided the required information to determine the selection of technology insertion points for the LSDP, and to assess the impacts of applied technologies relative to the existing baseline.

4.0 IDENTIFICATION OF COMPLEX NEEDS AND PROBLEM SETS

The first step in determining which technologies would be demonstrated as part of the CP-5 LSDP was to identify which processes during the D&D of the CP-5 Research Reactor Facility posed potential problems (i.e., cost, safety hazards, exposure hazards) and would be good candidates for innovative technologies. These technologies would then be demonstrated in an effort to lower D&D costs, reduce personnel exposure, increase overall safety, and/or expedite the completion of the D&D process. The SA tasked the TSC to identify these processes and to determine which of them would be further developed into more precisely defined demonstration problem sets. TSC members in researching technologies for demonstration at CP-5 would then use these problem sets.

Recognizing the benefit of selecting technologies that have a broad application to a variety of stakeholders, the needs identification task was expanded to include the following market areas:

- CP-5 Reactor Facility
- DOE- Facilities
- DOE Complex-Wide Facilities
- Commercial Facilities
- International Facilities

The TSC reviewed documents such as the *CP-5 Cost Estimate*, the *EM Baseline Environmental Management Report (BEMR)*, the *Decontamination and Decommissioning National Needs Assessment*, the *Decommissioning Handbook*, and the *Oak Ridge National Laboratory Technology Logic Diagram* to identify the issues and problems encountered during D&D activities. Discussions were also held with commercial nuclear partners and international stakeholders. TSC members searched for those processes that were potentially high-cost, or high-risk activities (based on safety or personnel exposure), or required technologies to support the As Low As Reasonably Achievable (ALARA) concept.

The TSC's research identified four categories of needs that encompassed common themes transcending two or more of the major market areas. These needs were established as the main categories under which all LSDP demonstrations would be grouped.

- Facility Characterization
- Facility and Equipment Decontamination
- Robotics/Dismantlement
- Worker Protection/Containment

These needs were further defined into the following problem sets used to research and evaluate innovative technologies for potential demonstration at CP-5.

4.1 Facility Characterization

Characterization demonstrations were required to fulfill the following CP-5 D&D activities:

- Automated floor survey to map contamination
- System to survey the internal surfaces of drain lines
- Automated wall surveys
- Method to determine if graphite blocks contain lead
- Characterization of rod storage liners and retention tank sludge

4.2 Facility and Equipment Decontamination

CP-5 houses a variety of decontamination scenarios, which required various technologies including:

- System to clean the internal surfaces of rod storage liners
- System to filter and clean storage pool water
- System to decontaminate the hot cell

- System to remove and package tank sludge
- System to decontaminate concrete floors and walls

4.3 Robotics / Dismantlement

To enable distance and maintain the ALARA philosophy, robotics were necessary for:

- Removal and size reduction of bioshield components, reactor vessel, and the graphite.
- Removal of piping and wiring above shield plugs
- Size reduction and packaging of storage pool components

4.4 Worker Protection / Containment

Worker protection was an issue of concern. Needed technologies included:

- A system to allow longer work times and reduce heat stress while in protective clothing
- Types of worker protective clothing
- Work area containment

5.0 TECHNOLOGY SELECTION COMMITTEE

5.1 Purpose and Objectives

The SA utilized a TSC to complete the selection of appropriate technologies for demonstration in the CP-5 LSDP. The TSC was responsible for evaluating industrial issues, researching potential technologies, evaluating candidate technologies and selecting technologies for recommendation to the SA Board. The TSC represented a wide diversity of backgrounds and combined knowledge from commercial industry, national laboratories, academia and government projects. Additional industry experts were also invited to participate in the TSC meetings. The TSC developed criteria and a methodology to identify, evaluate, and select candidate technologies for demonstration at the CP-5 facility.

5.2 Technology Selection Committee Structure

The TSC was comprised of one voting member from each SA member organization. The TSC Chair reported directly to, and was a member of, the SA Board. The TSC Chair was provided by ICF.

5.3 Activities / Duties / Responsibilities

The TSC was responsible for the following activities:

- Identifying the needs and problems. The TSC listed the needs for both CP-5 and the DOE Complex in order to identify technologies for demonstration. (See Section 4.0 for a discussion of these needs.)
- Developing selection criteria. The TSC developed the criteria for evaluating innovative technologies for demonstration at CP-5. (Section 5.5 includes a complete description of these criteria.)
- Searching for innovative technologies. Using the resources discussed in Section 5.4, the TSC Leads (TSC-L) searched and identified potential technologies for demonstration.
- Evaluating and recommending technologies for demonstration. Using the selection criteria developed above, the TSC-Ls evaluated and recommended technologies for demonstration at CP-5.
- Specifying performance indicators. For each technology approved for demonstration, the TSC- L developed performance indicators used to determine the success or failure of the technology demonstration.
- Assigning a test engineer to each demonstration. The TSC-L assigned to each technology a Test Engineer responsible for the preparation of the test plan, the demonstration and evaluation of the technology and preparation of the ITSR, Technology Technical Data Report and the Technology Demonstration Summary Sheet.

5.4 Identification of Potential Technologies

TSC-Ls used the following resources to identify potential technologies for demonstration at CP-5:

- *DOE*- The DDFA sponsored the research and development of several technologies for the D&D of DOE facilities. Technologies that could meet the market needs identified by the TSC were evaluated for demonstration.
- *Internet searches*- References such as the Thomas Register of American Manufacturers℠ were used to locate vendors of technologies being evaluated for demonstration.
- *Department of Defense/Industry Aerospace Coating Conference*- Commercially available technologies being used for the removal of hazardous materials were identified and evaluated for potential demonstration at CP-5 in the area of facility decontamination.
- *Forums and conferences*- Commercially

available technologies were identified for evaluation.

- *Best in Class experience*- Technologies were identified through personal knowledge and work experience of the members of the SA.
- *Exposure and contacts*- Technologies were identified through networking with other D&D professionals.
- *Global Network of Environmental Technologies (GNET)*- Technologies were identified through the GNET database.

In searching for new and innovative technologies to demonstrate at CP-5, TSC members looked for:

- Emerging technologies
- Technologies which could substantially improve on the baseline technology
- Commercial technologies which have not been successfully introduced to the DOE Complex
- New applications of existing technologies

5.5 Selection / Evaluation Process

Once identified, potential technologies were evaluated using a common set of technology selection criteria. Information was collected from manufacturers' literature, reports, publications and interviews. These data were used to perform an objective evaluation using a numerical ranking process. The endpoints of the ranking scale for each criterion are described below (See evaluation form - Appendix A).

The technology selection criteria were divided into three main sections depending on their importance. Any technology not meeting all the criteria listed below was dropped from further evaluation.

The following criteria required satisfaction before selection of a technology for detailed review.

State of Maturity

The technology must be "field test ready" for a large-scale demonstration. The LSDP should serve as one of the few remaining steps in commercializing the technology and achieving broad acceptance across the DOE Complex and commercial sector. Technologies requiring substantial additional research and development were not considered as candidates for demonstration. In unique cases, the TSC suggested two or more technology providers to meet a specific DOE Complex need.

> Numerical evaluation:
> 1= Not ready for demonstration
> 5= Used commercially for identical or similar purposes

Transportability to CP-5

The technology must be capable of being transported to the CP-5 reactor.

> Numerical evaluation:
> 1= Difficult or impossible to transport technology
> 5 = Minimal effort to transport; can be moved by one or two persons and shipped via commercial carrier

Applicability to CP-5 Demonstration Needs

The technology must be able to address a need for the remaining scheduled D&D activities at CP-5. Technologies that do not apply to the CP-5 D&D process may be considered by the SA on future demonstration projects.

> Numerical evaluation:
> 1= Demonstration does not fit within any of the identified technology criteria or problem sets
> 5 = Demonstration meets one or more of the specified needs

Performance Indicators

It must be possible to develop quantitative performance indicators (measures of success) by which the technology can be evaluated during the demonstration. The TSC considered the value of the information that would be generated from a large-scale demonstration.

Numerical evaluation:
1= Difficult to establish measures that define success of the demonstration
5= Demonstration has clearly defined performance indicators that include cost, dose and waste measures

The following criteria are of high importance to ensure a technology demonstration would provide maximum benefit to the LSDP.

Application Across Complex
The technology should be capable of being applied across the DOE Complex and of resolving multiple problem sets. Technologies developed for a single application would receive a lower evaluation.

Numerical evaluation:
1= Only applicable at one DOE site or facility and not useful at others
5= Applicable at any DOE site or facility

Cost/Benefit (Complex-Wide)
The technology should have applicability across a wide range of DOE facilities and commercial plants with an associated overall cost savings (or cost avoidance) to each of those facilities. Consideration was given to ALARA issues.

Important non-cost factors, such as: industrial safety improvements, production rate increases, radiation dose reductions, schedule acceleration, and waste volume reduction.

Numerical evaluation:
1= Cost to deploy does not realize a tangible benefit
5 = Demonstration provides a significant improvement over the baseline.

Compatibility with CP-5 D&D Baseline Schedule
The technology demonstration should be able to fit within the remaining scheduled D&D activities. Technologies that could be integrated in the CP-5 D&D process were considered by the Alliance on future demonstration projects. The technology demonstration could in no way compromise worker safety at the CP-5 facility.

Numerical evaluation:
1= CP-5 schedule has to be adjusted significantly to accommodate the demonstration
5= Demonstration provides an activity that fits CP-5 schedule and supports a vital baseline activity previously identified in the CP-5 baseline

The following criteria are important to ensure the technology demonstration would provide maximum benefit to the LSDP.

Improvement Over CP-5 Baseline
The technology should be able to improve upon the current industry technologies and processes, which constitute the CP-5 baseline. Successful demonstration of the technology should provide the opportunity for overall cost savings or cost avoidance relative to the CP-5 baseline. Special consideration should be given to worker safety improvement, acceleration of schedule, dose reduction, and waste minimization.

Numerical evaluation:
1= Cannot make significant improvement in progress of D&D of CP-5
5 = Improvement easily measured in dose or waste reduction, cost savings, cost avoidance or schedule reduction

Cost of CP-5 Demonstration
The overall demonstration cost should be considered. The willingness of technology providers to cost-share and the percentage of that cost share would be **key** factors in the technology selection. **Note:** All technology providers provided a minimum 30% cost share to demonstrate their technology.

Numerical evaluation:
1= All costs are passed to the LSDP, none are absorbed by the vendor
5 = No cost to LSDP for any aspect of the demonstration

Provider's Interest in Participating
The technology provider should demonstrate enthusiasm, support and willingness to demonstrate at CP-5 (including extent of cost share). In addition, the provider should demonstrate a willingness, ability, and potential plans to commercialize the technology following a successful demonstration.

Numerical evaluation:
1= LSDP must perform a large coordination role in the demonstration, and provider displays minimal willingness to work with LSDP/CP-5 personnel
5 = Provider performs all tasks and supplies all essential consumables for the demonstration and displays a strong make-it-happen attitude

Numeric scoring was the first step in screening technologies for acceptance as a demonstration. A full evaluation of some technologies addressed additional factors beyond those developed for a general screening. In addition, the TSC recognized the possibility of substantial error in the reliance on numeric scores alone. Therefore, the next step in the screening process was an open discussion by the TSC of each technology's merits with respect to its potential.

The open discussion was a subjective evaluation of technology in which the TSC-L described the technology, its use in the D&D process, and any relevant commercial experience. The TSC members then discussed the technology's potential to meet identified market needs, based on their practical experience. The broad-based experience of these individuals in commercial, commercial nuclear, and laboratory situations provided a comprehensive spectrum of input as to the suitability of technology for demonstration.

The TSC then voted on whether or not to recommend the technology in question for demonstration at CP-5. Those technologies recommended by the TSC were then presented to the SA Board for review and approval.

As listed within the four technology categories on Appendix B, the TSC reviewed approx. 63 separate technology offerings from 115 different vendors and recommended to the SA Board 23 technologies for demonstration, which produced 23 post-demonstration, one page Technology Demonstration Summary Sheets and 20 ITSRs.

Twenty detailed Technology Technical Data Packages (TTDP), summaries of technical data for the executed technology demonstrations, were developed and archived for the CP-5 LSDP. There were two technologies that were combined into one TTDP, and two TTDPs were not produced due to failure of the technologies to perform in the application. The TTDPs produced were not distributed since they served as support information to meet the specific needs of each ITSR author for the development of the ITSR.

6.0 TECHNOLOGY DEMONSTRATION PROCESS

In the early planning stages of the CP-5 LSDP, a series of activities were planned to take a technology, once selected by the TSC, from conceptual design to field execution to report completion. Figure 6.1 displays these steps in the required sequence, and assigns approximate duration and a responsible party for each. Figure 6.2 provides a simplified flow chart for the safety review and approval process in the LSDP Safety/Environmental Review Plan. This document identified the process under which the safety aspects of each technology were reviewed and approved by ANL-E line management responsible for compliance with federal regulations and DOE Orders related to nuclear facility safety.

6.1 Technology Procurement

Technology Specification and Vendor Information Requirements Preparation
Once a technology was selected for demonstration by the TSC, the respective TSC-L assigned a Test Engineer to determine the specifications for that technology. This included minimum sensitivity for characterization technologies, rate of material removal for decontamination technologies, National Institute of Occupational Safety and Health (NIOSH) requirements for worker health and safety technologies, etc. All of the TSC-L's actions were coordinated through the Technology Coordinator. The Technology Coordinator was the ANL individual responsible for the overall D&D of the CP-5 facility. The intent was to use the "Best in Class" expertise of the SA to propose a demonstration meeting selection criteria. In addition to the specifications, a request for information to assist in vendor selection and Test Plan development was generated by the TSC-L and Test Engineer and submitted with the RFQ.

Technology Cost Estimate Preparation
The TSC-L, in conjunction with the Test Engineer and the Technology Coordinator, prepared an estimate of the total cost of the demonstration, including SA and vendor costs. This provided the TSC with an understanding of the total demonstration cost before a large investment was considered, and gave the AA an estimate to support discussions/negotiations with potential vendors.

Issuance of Request for Proposal
Upon receipt of all pertinent information from the TSC-L, the AA issued a RFQ to all known suppliers of the technology to be demonstrated. The list of known suppliers was provided by the TSC-L. The intent was not to run Commerce Business Daily (CBD) advertisements or go to extreme lengths to find potential vendors, but rather to rely on the knowledge and experience of the TSC, TSC-L, and Test Engineer. The RFP/RFQ contained the specifications, information requirements, and vendor cost-sharing requirements.

Evaluation of Proposals/Bids
Upon receipt, proposals were transmitted by the AA to the TSC-L, Test Engineer and Technology Coordinator. While cost was a significant consideration, it was not the sole criterion in selecting a vendor. Other criteria such as schedule, technology-specific applications and potential for complex-wide benefit were considered, and documented if the low bidder was not selected. For those proposals having a single source, or only one source that could meet the schedule or technical requirements, a justification for sole-source procurement was prepared and placed in the technology procurement file by the AA.

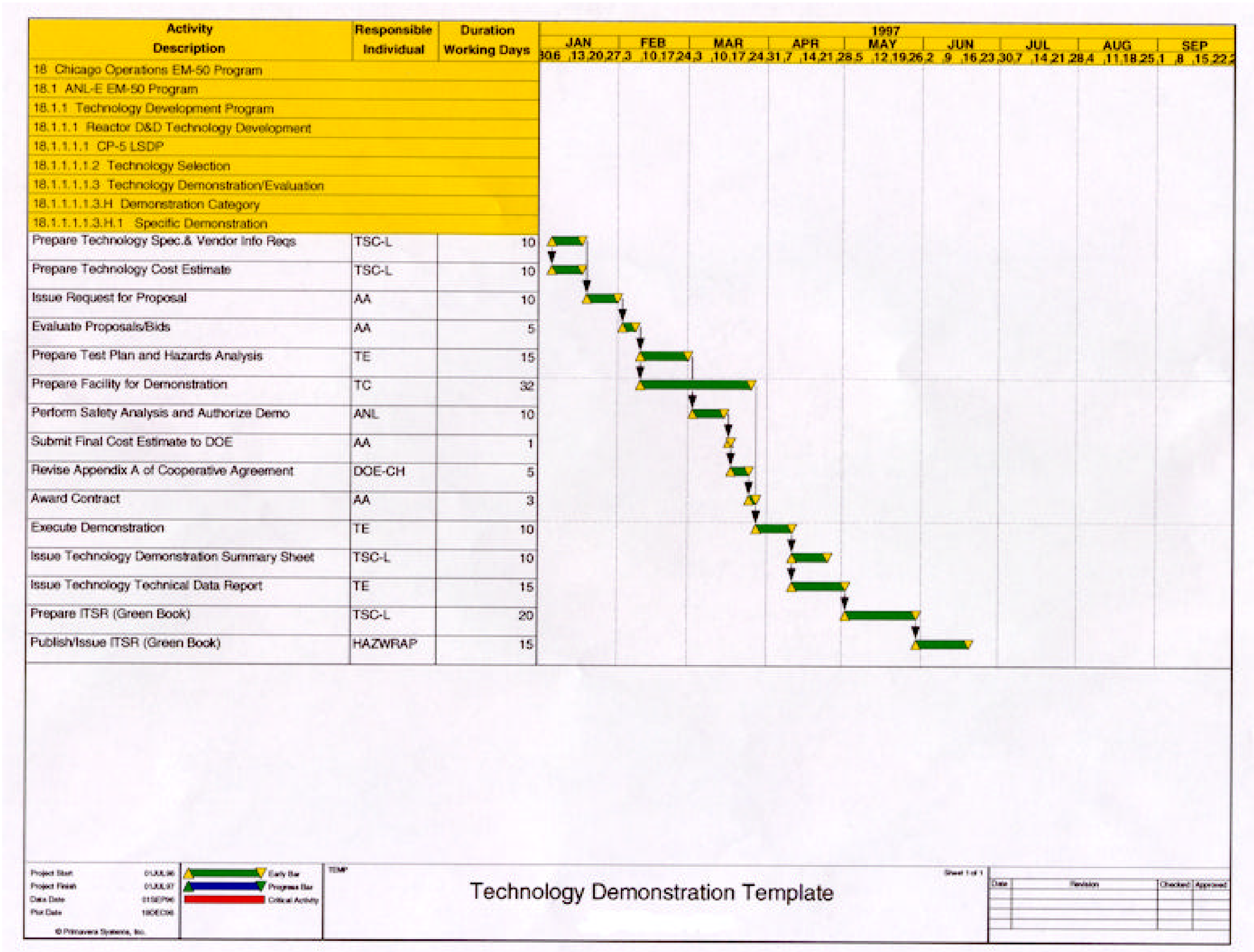

Figure 6.1 - Technology Demonstration Logic and Timeline

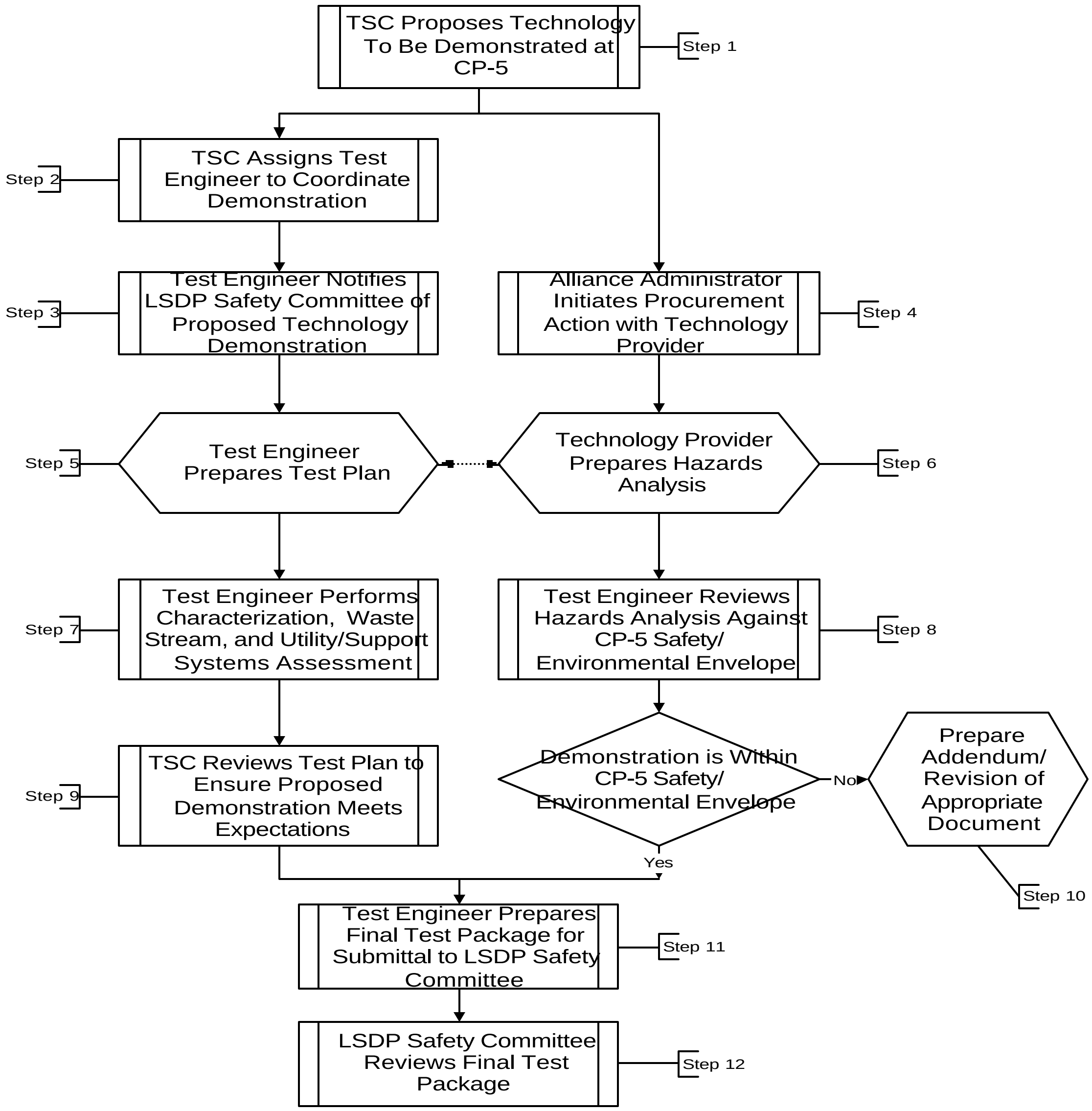

Figure 6.2 - Technology Review and Authorization Process

6.2 Demonstration Preparation

The Test Plan and Hazards Analysis were critical documents for the successful completion of each demonstration. For the purposes of review for appropriate data collection, and to ensure that the data collected was sufficiently standardized to allow cross-technology comparisons, ICF and the USACE provided a review function and supplied appropriate data forms and survey sheets as attachments to the Test Plan.

The ICF benchmarking group served as coordinator of the survey and data forms required for cross-technology comparisons, as well as the cost data requested by the USACE. ICF received the draft of the Test Plan, reviewed it for pertinent data collection needs not identified by the Test Engineer, and forwarded a copy to the USACE, which prepared the demonstration specific cost collection forms. ICF then assimilated all data collection needs into an attachment to the Test Plan and forwarded it to the Test Engineer for incorporation.

In addition to the Test Engineer, ICF and the USACE, the selected technology vendor was an integral participant in the preparation of the Test Plan. Upon selection, the vendor was contacted to assist in Test Plan preparation. A summary flow chart of the Test Plan development and review process is shown in Figure 6.3.

Hazards Analysis

Hazards Analysis ensured that all safety aspects of a demonstration were presented clearly to potentially affected personnel and that appropriate mitigative features were in effect before the demonstration was executed. In almost all cases, the currently authorized safety envelope consisting of the Safety Analysis Report, the Environmental Evaluation, and the Health and Safety Plan provided the conditions and requirements under which the demonstration was carried out. If a hazard was introduced which was not covered under the current envelope, separate direction was provided to ensure the hazard was minimized to the maximum extent reasonable.

Test Plan

The Test Plan served multiple purposes. It conveyed the technical expectations and limitations of the demonstration, as well as documented the commitments of all principals on mitigation of the hazards identified in the Hazards Analysis. In addition to the technical aspects, all data and information requirements to be collected by the Test Engineer were expressed in either attached data sheets and survey forms, or through directions contained in the text of the plan. Data were collected in any method or format convenient to the individual gathering the information, such as tape recordings, photos, video, log book entries, etc., as long as it could be transposed to a usable format for analysis at a later time.

Facility Preparation for Demonstration

Concurrent with Test Plan development and reviews, the CP-5 facility was prepared for the demonstration. This involved logistics arrangements for support personnel, equipment and utilities, as well as assembling related supporting characterization or design/engineering information to support Test Plan development. In some cases this was as simple as providing previous radiological survey records, while other demonstrations involved significant modifications to building systems or collection of additional characterization data. This activity was not a schedule driver unless the preparations were so extensive as to delay execution of the demonstration.

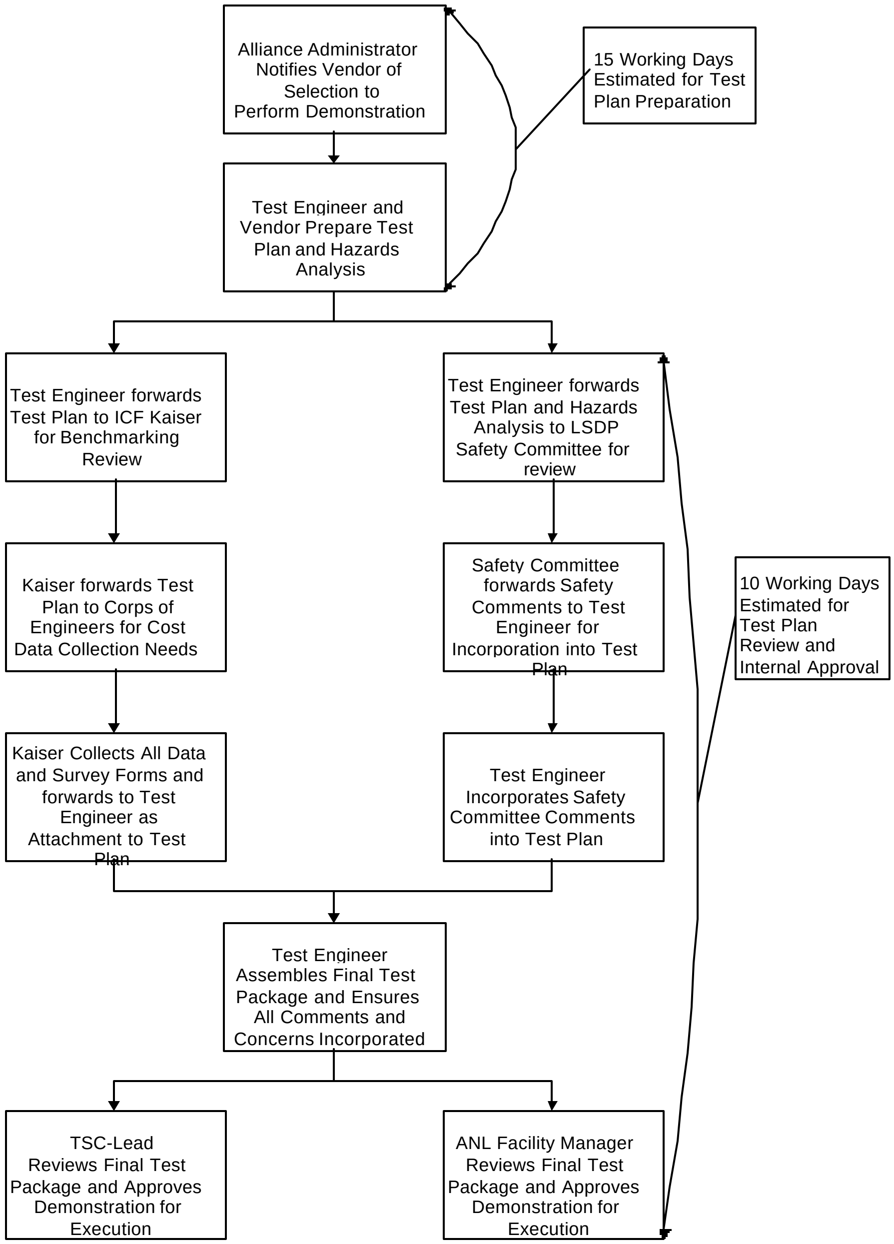

Figure 6.3 - Test Plan Development/Data Collection Process

Performance of Safety Analysis and Authorization of Demonstration
The *LSDP Safety/Environmental Review Plan - PP-1.1-100, Revision A-1, dated June 1996*, contains the requirements and process for the safety review of all technologies. This document is part of the Cooperative Agreement and was referenced in all contracts and agreements with technology vendors. The TSC-L was responsible for completing the Hazards Analysis and for coordinating the ANL technology authorization memo.

6.3 Demonstration Authorization

Submittal of Final Cost Estimate to DOE
Once the Test Plan and contract negotiations were complete, all parties were aware of roles and responsibilities, and final schedule determinations were made, the AA forwarded to the DOE Contracting Officer a package containing the vendor proposal, the SA demonstration cost estimate, and the ANL-E Facility Manager's authorization to perform the demonstration.

Revision to the Payable Milestone Schedule of the Cooperative Agreement
An appendix of the Cooperative Agreement presented the Schedule of Payable Milestones. Once the DOE Contracting Officer received the Final Cost Estimate Package, a fixed price task order, in the form of a revision to the Payable Milestone Schedule of the Cooperative Agreement, was issued to the SA for performing the demonstration. The Payable Milestone Schedule listed the technologies to be demonstrated, vendor costs and required vendor cost share. It should be noted that until the Cooperative Agreement was revised, there was no guarantee of payment for the effort expended to this point.

Award of Contract
Upon receipt of Cooperative Agreement Payable Milestone Schedule revision, the AA awarded a contract to the technology vendor. The approved Test Plan and specific schedule for execution of the demonstration was also sent to the vendor.

6.4 Demonstration Execution

The vendor would arrive on site, receive appropriate training, have all equipment and materials off-loaded and surveyed by health physics technicians and inspected by safety personnel (ANL-E industrial hygiene and fire protection organizations would be involved if appropriate), set up and checkout all equipment and perform a final walkdown of systems by appropriate inspectors. Once all requirements were met, the technology demonstration was allowed to proceed. The Test Plan was the controlling document for execution of the demonstration. The specific requirements and procedures contained in the Test Plan were strictly adhered to throughout the performance of the demonstration. Once completed, all equipment and materials were disassembled and surveyed for contamination, and disposition of waste and contaminated equipment were determined.

For those relatively expensive components which could not be decontaminated for unrestricted release, and which the vendor did not wish to dispose as radioactive waste, the technology vendor made arrangements for shipment to an organization licensed by the Nuclear Regulatory Commission, or to an agreement state, to hold the material for further decontamination or store it for future work. The SA budgeted for minimal effort on decontamination and survey of equipment used in demonstrations. Extraordinary efforts were not expended on salvaging vendor equipment.

6.5 Demonstration Evaluation and Reporting

Issuance of Technology Demonstration Summary Sheet
Shortly after the completion of a demonstration and demobilization of the technology, a one-page summary including the description of the technology, a general overview of the demonstration and a preliminary summary of results was developed and transmitted to people and organizations having a potential need for the technology (Appendix C).

Issuance of Technology Technical Data Package
The purpose of the Technology Technical Data Package was to provide a central collection point for all of the data and information collected over the course of the demonstration. It contains all data and survey sheets, notes collected during the demonstration, and any other pertinent information necessary to assess the effectiveness of the technology against specifications and expectations. This package was also intended as a record of all activities performed to allow for future reconstruction of the demonstration.

Preparation of Innovative Technology Summary Report (ITSR)
Using the November 1996 "Draft" Preparation Guidance for the Office of Science and Technology's ITSRs, a summary of the technology and the demonstration was written. The ITSR also provides a comparison of performance and costs between the innovative technology and the CP-5 baseline technology. The USACE prepared the cost analyses while the Test Engineer was responsible for the remaining ITSR sections.

Publish/Issue Innovative Technology Summary Report
ITSR preparation guidance provided for a relatively elaborate review process, which was complied with by request of the project sponsor (FETC). Once the SA was satisfied with the draft ITSR it was sent to the DDFA for review and approval. The DDFA reviewed and approved the document for publication with concurrence from the Headquarters Manager for the DDFA. The ITSR was then published by the DDFA through the Government Printing Office and distributed to a list of D&D professionals. The requirement for ITSRs evolved as the project progressed. (Appendix D).

6.6 Facility Preparation

In order to deploy the innovative technologies associated with in-situ reactor dismantlement, extensive modifications to the CP-5 ventilation system were required. The introduction of the Dual Arm Work Platform and the Rosie Mobile Robotic Work Platform precluded the use of a temporary containment tent and local ventilation, as originally envisioned. While these changes required a significant investment in the support systems necessary to carry out in-situ dismantlement, the overall methodology change led to a greatly enhanced worker health and safety program.

To allow real-time, direct viewing of the operations in progress on the reactor floor, modifications were made to the second floor control room to provide shielding and an observation gallery. This facility enhancement permitted more than 250 people, during the duration of the LSDP, to enter the robotic control room and directly observe the robotics and converse with the operators while operations were ongoing. This direct interface between problem holders and dismantlement personnel was extremely valuable in providing a direct communications link between D&D planners, engineers, operators and managers.

6.7 Incorporation into CP-5 Baseline

Many of the successfully demonstrated technologies have been, and will continue to be, incorporated into future work at CP-5, as well as into other D&D projects scheduled in the future at ANL-E. Many of the characterization technologies have been, and are continuing to be, deployed to replace baseline technologies. This transition to newer, innovative technologies will continue for the foreseeable future, based directly on the experience gained and substantiated improvement as documented during the demonstrations. This positive result is due to the communication of data from the LSDP at CP-5. Other technologies associated with decontamination, dismantlement, and worker health and safety will continue to be implemented as applications are identified. As out-year projects approach their execution dates, these technologies will formally be brought into the planning process, and are expected to significantly reduce the total project cost for D&D of these facilities.

7.0 DEMONSTRATIONS

The following sections outline the technologies demonstrated and basic results when compared to the baseline. Differences in the amount of work, scope of work, location on site, and location of specific DOE sites may cause cost estimates of the baseline and innovative technologies to vary from those reported in the ITSRs and this final report. Cost analyses for both of these reports were based on demonstration data and site-specific factors for each technology demonstrated.

The tables list general trends in the results based on the size and scope of the demonstration completed for this project. All of the detailed information about the technology demonstrations can be found in the ITSR for the specific demonstration desired. See Appendix D for a list of available ITSRs.

7.1 Characterization Technologies

Improved characterization technologies are necessary in order to better address release criteria and standards. Industry accepted baseline processes have high application costs and expose workers to industrial hazards and radiological and hazardous materials.

Prior to facility remediation and treatment, the DOE will be required to characterize more than 7,000 contaminated sites, 1.5 million barrels of stored waste, 385,000 m^3 of high-level waste in tanks, 1,000,000 tons of metal and 23 million cubic meters of concrete in contaminated buildings that require disposition. In addition, monitoring technologies are needed to ensure worker safety and effective cleanup during the remediation, treatment, and site closure processes.

Characterization technologies for the CP-5 LSDP were selected with these challenges in mind. Equally important was close integration with ongoing D&D activities at the ANL-E CP-5 research reactor.

As a result, characterization technologies were selected in three major categories:

- *Piping Internals Characterization* - These devices were selected to allow in-situ radiological and/or visual characterization of various configurations of buried or embedded piping. The general baseline technology was piping extraction/excavation followed by manual sampling.
- *Surface Characterization* - These devices were selected to provide alternatives to manual radiological surveys of building structures.
- *Physical Sample Characterization* - These devices were selected to allow in-situ analysis of non-radiological contaminants, as an alternative to local sampling with off-site laboratory analysis.

During the CP-5 LSDP, a total of eight characterization technologies were demonstrated and evaluated covering each of the three categories.

7.1.1 Comparison of Pipe Characterization Technologies

Two innovative technologies for characterizing the level of contamination in buried or embedded pipes were demonstrated at CP-5 as part of the LSDP. For evaluation purposes, these technologies were compared to the baseline technology of excavation, dismantlement and surveying of a section of pipe. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria for grouping of similar technologies. Comparison results are presented in Table 7.1

Pipe Crawler®

Pipe Crawler® is a pipe surveying system, marketed by Radiological Services, for radiological characterization and/or free release surveys of piping systems. The technology employs a family of manually advanced wheeled platforms, or crawlers, fitted with one or more arrays of thin Geiger-Mueller (G-M) detectors operated from an external power supply and data processing unit. Survey readings are taken in a step-wise fashion. A video camera and tape recording system are used for video surveys of pipe interiors prior to and during radiological surveys.

Pipe Crawler® successfully demonstrated its ability to perform characterization of radioactive contamination in buried and embedded piping. This offers the potential for significant cost savings over the baseline approach to excavate, dismantle, and dispose of the piping. Radiological surveys were performed in thirteen rod storage holes of 5”, 6” and 12” diameter and with a total length of 162 ft and in 25 ft of two 12” embedded vent lines.

Pipe Explorer™

The Pipe Explorer™ system is a characterization technology by Science & Engineering Associates, Inc. that uses a pneumatically operated airtight tubular membrane to tow radiation detectors and video cameras into pipes. When pressurized, the membrane inverts into a pipe with adequate force to tow the characterization tools through the piping, providing a clean conduit for the sensors to travel through. To retrieve the system, the process is reversed. The Pipe Explorer™ can thus be used to move a characterization tool forward and backward through a pipe as the tool’s output and position are continuously recorded, providing detailed characterization of the location and amount of radioactive contamination in pipes.

The Pipe Explorer™ system was used to successfully survey three alpha-contaminated fuel-rod storage tubes. These tubes were 11.5 foot long, 5-inch diameter stainless steel set vertically with the top of the tube at floor level. The alpha detector was demonstrated for the first time at the CP-5 Research Reactor under the LSDP. A video survey along 153 feet of a 4-inch drain line from a manhole was also successfully conducted. A beta/gamma survey of a 4-inch drain line from a manhole was successfully conducted (137 feet was surveyed with a minimum detectable activity (MDA) of 4,250 dpm/100 cm^2 and 53 feet were surveyed with a MDA of 1,680 dpm/100 $cm^{2)}$.

The issue of potentially producing airborne contamination as a result of displacing air in the pipe with the deploying membrane was addressed in a 12-inch vent line. This was the first Pipe Explorer™ survey conducted into a long, large diameter pipe that was plugged at the end. The access pipe coupling design incorporated a high efficiency particulate air (HEPA) filter to clean exhaust air prior to its release.

7.1.2 Comparison of Surface Characterization Technologies

Four innovative technologies for characterizing the radiation field and/or level of contamination from surfaces were demonstrated at CP-5 as part of the LSDP. For evaluation purposes, these technologies were compared to the baseline technology of manual surveys performed by health physics technicians. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria for this grouping of like technologies. Comparison results are presented in Table 7.2.

GammaCam™

The GammaCam™ system designed by AIL Systems is designed to provide two-dimensional information on the position and relative strength of gamma-ray radiation fields located a few feet to several hundred feet from the observer. The system consists of a portable sensor head that contains both gamma-ray and visual imaging systems and a portable computer for data acquisition and display. The computer can be located several hundred feet from the sensor head.

The GammaCam™ system performed well during the CP-5 demonstration by successfully providing two-dimensional color images of gamma radiation fields superimposed on a corresponding visual black and white image. No significant problems with the system were identified in the three-day test, despite considerable movement and relocation of the device. Using the GammaCam™ system in determining shielding requirements and positioning shielding will result in a significant reduction in the radiation dose received by operating technicians.

Training in the setup and use of the GammaCam™ is relatively easy and can be completed in a few hours. Due to the characteristics of the imaging system, a full day of training is required to properly interpret the resulting images.

In Situ Object Counting System

The In Situ Object Counting System (ISOCS) developed by Canberra Industries is a portable, easy-to-use germanium based spectroscopy system designed to provide information on the type and amount of radioactive material present in situ. The ISOCS system consists of (1) an ISOCS characterized Germanium detector with portable cryostat, (2) a cart support for holding the detector, lead shielding and collimators, (3) an InSpector portable spectroscopy analyzer, (4) a portable computer with Genie-PC software, and (5) the ISOXSW in situ calibration software. The ISOCS contains a built-in shielding code that identifies radioactive isotopes and quantitatively assays the radioactive contents of containers, surfaces and samples. The system is able to collect data in the background while performing real-time shielding or report calculations.

The Canberra ISOCS system performed well during the CP-5 demonstration by successfully obtaining data over a wide range of objects and surfaces. No problems with the system were identified in the three days of tests, despite considerable movement and relocation of the device. The high-resolution Germanium detector and spectroscopy system were easy to use and the associated databases provided useful information on peak identification in situ. Operation of the ISOCS system is relatively simple, but some training is required. In addition, the use of the assaying software requires considerable experience in modeling the source distribution.

Mobile Automated Characterization System

The Mobile Automated Characterization System (MACS) was developed by Oak Ridge National Laboratory (ORNL) and the Savannah River Technology Center (SRTC) as an automated floor surface contamination characterization system. It is designed for unattended operation during the collection, storage and analysis of large, open floor areas.
The system demonstrated at CP-5 was equipped with scintillation detectors for measuring alpha and beta emitting contamination, although other types of detector systems could be installed on the unit. At this time MACS is not capable of performing surveys along floor/wall boundaries, directly around the base of obstacles, or in areas too small for the system to maneuver.

Based on the results of the demonstration, MACS' greatest application would be in large open areas, which need to be surveyed repeatedly. In addition, the color graphics capability of the MACS to illustrate contamination locations is one of the system's greatest assets. This enables easier visual identification of contaminated areas by referencing color maps.

Downtime was experienced during the demonstration due to numerous survey and hardware errors. Further development of MACS would improve its reliability and take full advantage of its capabilities.

SRA Surface Contamination Monitor

The Shonka Research Associates (SRA) Surface Contamination Monitor (SCM)/Survey Information Management System (SIMS) is designed to perform alpha and beta radiation surveys of horizontal and vertical surfaces. The SCM consists of a position-sensitive gas proportional-counter mounted to a motorized cart. Data are typically measured for each 5-cm^2 region along a survey strip defined by the width of the proportional counter and the distance the cart has traveled forward in a straight line. Detector widths can vary between 0.5 and 5 m. The system records the data from each region and provides visual indication of the measured activity to the operator on a Liquid Crystal Display (LCD) screen. The large amount of data automatically recorded by the system is processed in the SIMS. This software combines the data from individual strips into a uniform grid that covers the surveyed area. The data within this grid can be viewed and analyzed by a wide range of image processing algorithms.

The SRA SCM/SIMS technology performed well during the demonstration by successfully detecting beta surface contamination and producing high-quality data reports. No significant problems with the system were identified. Significant time and cost advantages over manual surveys, even in facilities with small, irregularly shaped rooms, can be realized by using the SRA. This is true for surveys involving general surveillance and routine documentation requirements. For free-release surveys the cost advantage of the SRA system would be even greater, although these tests did not explicitly address that case. The automatic report generation feature is fast, and provides a detailed summary of the survey that would meet regulatory needs for documentation.

Training in the setup and use of the SCM is relatively easy and can be done in less than a half day. Use of the SIMS is also easy to learn for users familiar with standard Windows® programming.

7.1.3 Comparison of Physical Sample Characterization Technologies

Two innovative technologies for characterizing the level of contamination in physical samples were demonstrated at CP-5 as part of the LSDP. For evaluation purposes, these technologies were compared to the baseline technology of manual sample acquisition and laboratory analysis. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria for this grouping of like technologies. Comparison results are presented in Table 7.3.

Field Transportable Beta Counter

Triangle Research has developed a Field Transportable Beta Counter system to count solid media. The technology is a novel detection device for the qualitative and quantitative measurement of beta emitters. It is a portable instrument (not hand-held) which uses solid scintillation, coincident guarded counting and employs low-background photomultiplier tubes and low-noise preamplifiers to assay filters, swipes and other solid media. The instrument can detect beta-emitting nuclides such as Tc-99 and Sr-90 with detection limits in the 20 pCi range (with shielding). Full analysis can be achieved in 30 minutes depending on the background at the site. The dry scintillation counter used in combination with an element-selective technology eliminates the mess and disposal costs of liquid scintillation cocktails. Software in the instrument provides real-time spectral analysis.

The prototype was able to generate quantitative and qualitative data rapidly in a “field” situation.

This was accomplished for sources containing Tc-99, Sr-90, Co-60 and Cs-137. Two samples containing radioactive material were recovered from the CP-5 building with results produced within 30 minutes of counting. Over the two day demonstration period, 25 separate analytical measurements were made. A total of 20 personnel-hours spent at CP-5 included orientation, unpacking, setup, sample collection, sample processing, measurements, troubleshooting, breakdown, packing and removal.

Portable X-ray Fluorescence Spectrometer

The X-ray Fluorescence Spectrometer (XRF) analyzers, produced by TN Spectrace, use X-ray fluorescence data to provide rapid, non-destructive, real-time, elemental information on a variety of materials including surfaces, soils, liquids, or thin films. X-ray fluorescence is a phenomenon in which atoms of a given chemical element emit characteristic X-rays when excited by radiation having an energy close to, but greater than, the binding energy of the element's inner shell electrons. Because every element has a different electron shell configuration, the energy spectrum of each element's characteristic X-rays is unique to the element. Consequently, by measuring the peak energy of X-rays emitted by a sample exposed to an appropriate radiation source, it is possible to identify the elements present in the sample. Moreover, because the intensity of the characteristic X-ray emission is proportional to the number of atoms being excited, the X-ray fluorescence spectrum can also be used to measure each element's concentration.

In situations where the precision, accuracy, and detection limits of the XRF technology are consistent with the data quality objectives of a site characterization project, XRF is a fast, powerful and cost-effective technology for identifying and measuring concentrations of chemical elements, particularly metals. The instruments used in the demonstration were lightweight and convenient to operate in the field. Software was easy to operate for both instrument control and data transfer from instrument memory to personal computer. Performance of the instruments was consistent with vendor specifications. Multiple measurements on individual samples gave reproducible results.

Direct analysis of a used HEPA filter was unsuccessful because the structural configuration of the filter includes a wire-mesh screen, which encloses the filter medium and prevented positioning of the instrument probe on the contaminated surface. Intrusive sampling may be necessary to apply the XRF technology to certain types of materials.

Table 7.1 Comparison of Pipe Characterization Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Dismantle/Survey (Experiential Data)	Pipe Crawler (Radiological Services, Inc.)	Pipe Explorer (Science & Engineering Associates) {based on vendor literature}
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • Detectable contaminants • Isotopes • Minimum level • Reliability/validity	• Embedded pipes • (Not concurrently demonstrated) • α, β, γ, debris • Instrument specific • Instrument specific • Small sample of pipe (may not be representative of contamination)	• 2" -18" diameter pipes • Embedded drain lines, air vents, fuel rod storage holes • β, γ, debris • Not differentiated • Below regulatory limits • Entire pipe length (<200') surveyed	• 2"-40" diameter pipes • Embedded pipes, fuel rod storage holes • α, β, γ, debris • Not differentiated • Below regulatory levels • Entire pipe length (<250')
2. Safety	• Hazardous work conditions • Cross-contamination • Need for worker protection	• Heavy equipment, trenching & radiological hazards • High potential • High	• Occasional confined spaces work • Low potential; none observed • Very low	• Radiological, electrical • Very low potential because of pneumatically deployed membrane; none observed • Very low
3. Cost	• Product vs. service • Rental vs. purchase • Cost • Consumable items	• Site or contractor personnel • Site or contractor equipment • High • Variable, depending on site soil/pipe conditions	• Service provider only • Rental • 55% of baseline • Minimal	• Service provider only • Rental • Variable can be both slightly higher or lower than baseline • Membrane, ~0.5 cu.ft./200 lin.ft. of pipe surveyed
4. Speed and Responsiveness	• Deployment means • Availability and timing of results • Need for additional calculations or documentation	• Heavy equipment • Must wait for excavation, dismantlement & sample analysis • Instrument-specific	• Wheeled tractor plus monitoring devices • Real-time results • None required	• Pneumatically deployed membrane and detectors • Real-time results • None required
5. Waste Generation	• Type (other than PPE) • Volume • Integration with radwaste system	• Soil • Variable • No	• Rags for decontamination • Minimal • No	• Membrane • Minimal • No
6. Readiness Status	• Commercial availability • Field-tested • Proprietary	• Yes • Yes • Instrument-specific	• Yes • Yes • Yes	• Yes (β,γ, video); No (α) • Yes • Yes
7. Support Requirements	• Utilities • Personnel • Facility modifications • Required reviews	• Variable, depending on equipment • Labor intensive • Trenching • Major	• Electrical: 110 VAC; Compressed air < 100 psi • Vendor (2) • None • None	• Electrical: 110 VAC • Vendor (2) • None • None
8. Mobilization & Demobilization	• Transportation • Size/portability • Setup time • Need for decontamination	• Trenching equipment • Backhoe • High • Major	• Van • 18"x36" (hand-held); < 50 lb. • 2 hours • Wipe down with wet rag; no chemical decontamination required	• Truck • Large canister, rolls on wheels • <1 hr. • Minor (pneumatically deployable membrane protects monitor)
9. Ergonomics	• Ease of use • Worker comfort • On-site training/skill level • Independence	• Time-consuming task • Physical labor • Skilled operators needed • Constant hands-on operation	• Easy to use; some physical effort involved • Some physical exertion required to manually advance crawler • None: operated by vendor personnel • Constant hands-on operation	• Easy to use; little physical effort involved • Good • None: operated by vendor personnel • Constant hands-on operation

Table 7.2 Comparison of Surface Characterization Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Manual Surveys (Experiential Data)	GammaCam (AIL System, Inc.)	In Situ Object Counting System (Canberra Industries, Inc.)	Mobile Automated Characterization System (Oak Ridge/Lockheed Martin)	Surface Contamination Monitor (Shonka Research Associates)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • Detectable contaminants • Isotopic identification • Minimum level • Reliability/validity	• Contaminated surfaces or radiation fields • (Not concurrently demonstrated) • Alpha, beta, gamma • No isotopic identification • Background • Decision quality data; lack of directional sensitivity	• Contaminated surfaces or radiation fields (shielded or unshielded sources) • Rod Storage Area floor and door; Cave Room covered access hole; Fuel Pool; Top of Reactor; Reactor Shield Block (GammaCam was mounted on both tripod and crane) • Gamma • No isotopic identification • 10 μR in 10 minutes at 1 meter • Directionally sensitive to better quantify source locations	• Wide range of contaminated object and surface configurations • CP-5 walls, floor, cask with 55-gal. Drums, small containers, and concrete core sample • Gamma • Any with gamma emitters • Above background • Reasonable agreement with baseline	• Large contaminated floor surfaces • Irregular concrete basement service floor of CP-5, 600 sq.ft. • Alpha and beta for demonstration, other detectors could be added • No isotopic identification • Background • Prototype had some computer CPU problems, but data validation against baseline was very good	• Unobstructed horizontal contaminated surfaces • CP-5 service floor and main floor (total area surveyed = 2,800 ft^2) • Alpha, Beta • No isotopic identification • Background (few 100 dpm) • Improved reliability and quality of collected data over baseline
2. Safety	• Hazardous work conditions • Cross-contamination • Need for worker protection	• Directly exposes workers to contamination and radiation • Contamination can be tracked from place to place • Personal protective clothing	• Can be remotely operated from considerable distance (200') to minimize personnel exposures • None occurred during demo • No more than baseline	• No more than baseline • None • No more than baseline	• Automated, unattended operation • None occurred during demo • No more than baseline	• Eliminated direct personnel exposures • None observed during demo; low possibility of tracking contamination on wheels • No more than baseline
3. Cost	• Product vs. service • Rental vs. purchase • Cost comparison • Consumable items	• Product (detectors) • Either (usually purchased) • ~$1.14/sq.ft. for comparable small survey area • None	• Product • Rental • Initial training costs and shipping charges are high; currently more expensive than baseline • None	• Both • Both • ~30% of baseline cost • None	• Product • N/A, prototype • ~6x baseline cost for small demo area surveyed • None	• Product and/or service • Purchase • Three-fold cost savings over baseline for simple characterization scenario • None
4. Speed and Responsiveness	• Availability and timing of results • Need for additional calculations or documentation	• Time intensive survey of multiple grid points within designated area with concurrent manual data recording (average survey rate ≅ 4 ft^2/min) • Subsequent analysis, graphing and reporting of raw data required (average data analysis time ≅ 8 ft^2/min)	• Immediate visual and numerical displays • Reports are generated by portable computer	• Real -time spectroscopy allowed for second measurement while first was being analyzed • None after calibration	• Immediate color visual and printed results • Reports generated by onboard computer	• Real-time data display (average survey rate ≅ 23 ft^2/min) • Detailed reports automatically generated by portable computer (average analysis rate ≅ 39 ft^2/min); time indexed videos produced
5. Waste Generation	• Type (other than PPE) • Volume	• None • None	• None • None	• None • None	• None • None	• None • None
6. Readiness Status	• Commercial availability • Field-tested • Proprietary • Future development	• Detectors commercially available • Extensive experience • No • Not Applicable	• Yes • Yes • Yes • Readouts at lower exposures; addition of range finder (source to detector); parallax considerations	• Commercially available • Yes • Yes • Allow cryostat to be tilted up or down without refilling	• Most components commercially available, total system is a prototype • CP-5 is first demo • Yes • Develop gamma detection capabilities, improve system reliability, improve on obstruction detection capabilities	• Yes • Yes • Yes • Gamma detection capability; improvements to survey orientation software; inclusion of manual survey data
7. Support Requirements	• Utilities • Personnel • Facility modifications • Required reviews	• None (self-powered detectors) • One to two • Temporary shielding in high radiation areas; long-handled tools • None	• 120 VAC @ 60 Hz, 250 watts • Two • None required • None	• 110 VAC or internal batteries • One • None • None	• 110 VAC for charging onboard batteries • Three for prototype • None • Yes, due to onboard laser	• 120 VAC, 20 amp; specialty counting gas P-10 @ 25 cc/min • Operable by one person • None required • None required
8. Mobilization & Demobilization	• Transportation • Size/portability • Setup time • Need for decontamination	• Hand-held detectors • Hand-held detectors • Calibration of detectors • None	• Air cargo • Portable (not hand-held); 19"x10"x15", ≅ 60 lbs. excluding portable computer • Less than one hour • None required following demo	• Van • 2' x 5' x 2' high/300lb. • 1 to 2 hr. • None	• Panel truck • MACS: 34"x57"x45" high/450 lb.; Control station: 36"x36"x48" high/200 lb.; Battery charger: 18"x18"x24" high/65 lb. • 5.5 hr. • None required following demo	• Van • 2'x2'x3'; 160 lbs. • Less than one hour • None needed following demo
9. Ergonomics	• Ease of use • Worker comfort • On-site training/skill level • Independence	• Repetitious readings at multiple locations • Tedious task • Health physics technician • None; labor intensive	• Provides two dimensional pseudo-color image of gamma field superimposed on black and white visual image • Good • Training required (≅ 8 hours) • Operates independently after set-up	• Good • Good • 48 hr. • Independent once parameters set	• Provides excellent color representation of relative levels of contamination • Good • Unknown, contractor personnel used • Operates independently after setup	• Automatic data collection with visual data displays • Good • Required training (≅ 4 hours) • Minimal operator intervention; manual guidance of direction of scan

Table 7.3 Comparison of Sample Characterization Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Manual Sample Acquisition and Laboratory Analysis (Experimental Data)	Field Transportable Beta Spectrometer (ANL-E & Triangle Research, Ltd.)	X-Ray Fluorescence (TN Spectrace)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • Detectable contaminants • Isotopic identification • Minimum level • Reliability/validity	• Contaminated surfaces, filters, swipes • (Not concurrently demonstrated) • α, β, γ • Isotopic identification by lab analysis • Below background • High-quality results and documentation	• Five solid samples, one liquid sample collected on selective disc • Next to CP-5 fuel storage pool • Beta emitters • Real-time spectral analysis • Two times background (60 dpm) • Field screening quality only at present	• Solid, liquid, thin-film, and powder samples • Floors, wall, ceilings, ducts, and HEPA filters within CP-5 • Elements of atomic number >32 • N/A • From a few ppm to percent levels • Comparable to baseline, but need regulatory approval
2. Safety	• Hazardous work conditions • Cross-contamination • Need for worker protection	• Fixed lab setting with corrosives and organic solvents • Unlikely • Goggles, gloves	• No chemicals used; passive analytical design • Unlikely • No more than baseline	• No chemicals used; passive analytical design • Unlikely • No more than baseline
3. Cost	• Product vs. service • Rental vs. purchase • Cost • Consumable items	• Service • Not Applicable • Variable, depending on specific analysis • Chemicals	• Product and/or service • N/A, prototype • Initial training costs are high; currently more expensive than baseline • Filters, swipes, selective membrane discs	• Product • Purchase • ~30% of baseline • None
4. Speed and Responsiveness	• Availability and timing of results • Need for additional calculations or documentation	• Must wait for sample acquisition, transit, and lab analysis (1-5 days) • None required	• Rapid turnaround (total time for set up, sample collection and preparation, results: 80 minutes [aqueous]; 65 minutes [swipe solids]) • Immediate computer generated reports	• Real-time results • Immediate computer generated reports
5. Waste Generation	• Type (other than PPE) • Volume	• Acids, organic solvents, resins, glass • Liquid scintillation cocktails: 20-500 ml per sample (mixed)	• Dry and/or liquid (no mixed waste) • Solid: 1 gram/sample dry membrane disc, swipes; Liquid: 1-4 liters extracted water effluent	• None • N/A
6. Readiness Status	• Commercial availability • Field-tested • Proprietary • Future development	• Numerous qualified labs available • Extensive • No • Not Applicable	• First generation prototype; not commercially available • None previous to CP-5 demo • N/A, prototype • Background reduction, multiple source identification, alpha detection	• Commercially available • Extensive • No • N/A
7. Support Requirements	• Utilities • Personnel • Facility modifications • Required reviews	• Availability of capable and qualified lab facility • More than two • None • Established procedures and protocols for chain of custody	• 110 VAC (< 1 amp); portable computer • Two • None (shielding may be required for below background counts) • None	• 110 VAC or internal batteries • One • None • None
8. Mobilization & Demobilization	• Transportation • Size/portability • Setup time • Need for decontamination	• Must transport samples to lab • Fixed lab facility • Minimal • Sample disposition and lab equipment cleanup	• Easily transportable • Portable, not hand-held (2'x3'x1', ≅ 15 lbs. excluding computer) • 30 minutes • None required during demo	• Easily transportable • Portable, ~19 lb. For hand-held probe plus electronics unit • 5 min. • None required during demo
9. Ergonomics	• Ease of use • Worker comfort • On-site training/skill level • Independence	• Two-step process • Standard laboratory conditions • Extensive lab training in chemical analysis procedures and protocols • Hands on analysis in lab	• Easy to use; highly mobile • Good worker comfort • Training required for on-site personnel to operate (≅ 2 weeks) • Requires personnel to operate	• Easy to use; highly mobile • Good worker comfort • ~2 hr. • Requires personnel to operate

7.2 Decontamination Technologies

Improved decontamination technologies are needed to address radioactively contaminated concrete and wastewater during the D&D process.

As buildings undergo the D&D process, concrete floors contaminated with radionuclides such as uranium, cobalt, and technetium must be decontaminated before final disposal. The two primary decontamination objectives for concrete surfaces are: (1) to reduce the potential for personnel and environmental exposure to contaminants during dismantlement and disposal; and (2) the reduction of surface contamination levels to meet established criteria for unrestricted use.

It is estimated that 23 million cubic meters of concrete will require disposition as 900 buildings undergo the D&D process. Current technologies used in the decontamination of concrete surfaces are often labor intensive, generate large volumes of secondary waste, and have relatively high operating costs. Innovative technologies are being developed with the goal of providing safer and more cost-effective alternatives that generate less secondary waste, thereby decreasing treatment costs for contaminated concrete surfaces.

In addition, contaminated water from fuel pools and sumps must be decontaminated prior to release from DOE facilities.

The suite of decontamination technologies for the CP-5 LSDP was selected with these challenges in mind. In addition, there was close integration with ongoing D&D activities occurring at the ANL-E CP-5 research reactor.

Decontamination technologies were selected in three categories:

Concrete coating removal decontamination - These technologies were selected for their ability to remove the coating/paint or top 1/16-inch from concrete floors.

¼-inch concrete removal decontamination - These technologies were selected for their ability to remove up to ¼-inch of concrete from the floor.

Liquid decontamination - These technologies were selected to remove contaminants from liquid waste such as water from fuel pools or sumps.

7.2.1 Comparison of Coating Removal and ¼ inch Concrete Removal

Seven innovative technologies for removing coatings from concrete were demonstrated at CP-5 as part of the LSDP. For evaluation purposes, these technologies were compared to the baseline technology of mechanical scabbling. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria for this grouping of like technologies. Comparison results are presented in Table 7.4.

The ANL-E baseline technology, mechanical scabbling, uses a manually driven floor/deck scaler suitable for thick coating removal and the surface preparation of large areas of concrete floors. This unit is equipped with 11 one-inch-diameter pistons that impact the floor at a rate of 2,300 blows/min/piston. An aluminum shroud surrounding the pistons captures large pieces of debris; however, an attached dust collection/vacuum system is not being used. Instead, a containment system (i.e., a plastic tent) is erected over the area to be decontaminated to minimize the potential release of airborne dust and contamination.

Advanced Recyclable Media System

The Advanced Recyclable Media System® (ARMS) technology, by Ecology & Environment, is an open blast technology which uses soft recyclable media. The patented ARMS Engineered Blast Media consists of a fiber-reinforced polymer matrix, which can be manufactured, in various grades of abrasiveness. The fiber media can be remade and/or reused up to 20 times and can clean almost any surface (e.g., metal, wood, concrete, lead) and any geometry, including corners and the inside of air ducts. When blasted at the surface of a substrate, the media compresses entrapping contaminants from the surface in its matrix. The fiber matrix transfers energy efficiently to the surface, minimizing rebound of the media from the surface into the air. This matrix can also absorb heated vapor injected into the blast unit from a vapor injection system, and transfer it to a surface for accelerated treatment or to maximize dust suppression.

The ARMS technology successfully blasted 262 square feet of flooring in the demonstration area at a rate of 41.9 ft^2/hr. This rate includes a crew of three persons performing the following tasks: blasting the floor, collecting the discharged media, sifting the media, and recycling the media back into the media feed unit. The demonstration began with 200 pounds (7.52 ft^3) of new media, which was recycled approximately 16 times during the blasting.

At the end of the demonstration, a total of 0.8 ft^3 of spent fines (<1/16-in) and large (>1/4-inch) pieces of concrete were collected and discarded as waste. The amount of media considered to be reusable was measured to be 4 ft^3. After the demonstration, the radiological level of the spent fines (<1/16-inch) was 3,000 dpm and the remaining reusable media (>1/16-inch) levels were measured to be 300-500 dpm. Blasting of the floor reduced the contamination levels in the demonstration from an area of total beta/gamma fixed contamination ranging from 3,200 to 263,200 dpm/100 cm^2, to four localized hotspots ranging from 4,000 to 19,000 dpm/100 cm^2 .

Centrifugal Shot Blast System

Concrete Cleaning Inc. is a commercial service provider that uses modified centrifugal shot blast machines to remove concrete and concrete coatings. The shot blast unit propels hardened steel shot at a high rate of speed to abrade the surface of the concrete. The rate of speed at which the machine is traveling and the volume and size of shot fired into the blast chamber determine the depth of removal. The steel shot is recycled and reused until it is too small to be useable. The unit can be used with a variety of dust collection systems. Concrete Cleaning Inc. modified a commercially available dust collection system with a HEPA filter for this demonstration.

The centrifugal shot blast technology removed the paint coating from the 800 square feet of concrete flooring in the demonstration area at a rate of 310 ft^2/hr within a proximity of 2 inches from the union of the floor and the wall and 5 inches around obstructions. This resulted in a reduction of the contamination levels from up to 5,300 dpm/100 cm^2 fixed total beta/gamma to levels measuring at or below background levels. The self-propelled unit significantly reduced operator fatigue and has the potential to reduce exposure in highly contaminated areas.

The dust collection system has the potential to significantly reduce the amount of airborne radioactivity during D&D activities, thereby potentially reducing personal protective equipment (PPE) requirements. Modifications made by Concrete Cleaning Inc. to the dust collection system were not adequately designed. The leg extensions that were added did not adequately support the dust collector, causing the unit to be unstable. The funnel and drum lid system was not flexible enough to allow the waste drum to be easily removed from under the vacuum. Concrete Cleaning Inc. has initiated corrective actions to eliminate these problems.

Flashlamp

The Starboldt™ flashlamp system is a self-contained proprietary system for coatings removal and decontamination. It uses xenon flashlamps to remove surface coatings from substrates. The system operates by pulsing an electric current at the rate of 4 to 7 Hertz (Hz) to a xenon gas-filled quartz lamp. With the aid of a reflector housing, the emitted light is concentrated and projected onto the surface coating. The coating absorbs the light energy, decomposes into a fine ash, and is removed from the surface by means of a debris scrubber and vacuum filter system attached to the head.

This demonstration tested Polygon Industry's Starboldt™ flashlamp technology for its ability to decontaminate approximately 600 square feet of concrete flooring by removing the coating layer without removing the concrete. The system was operated for approximately 8 hours; however, the technology was not able to remove the entire coating. During the demonstration, the electric current was adjusted several times in an attempt to establish the optimum Hertz setting, with the setting of 7 Hertz determined to be the most effective. Although in some areas the coatings were removed down to the concrete, in most areas of the demonstration the bottom layer of paint or primer coating turned to a black "soot-like" residue of varying thickness, which remained fixed to the concrete. The demonstration was stopped prior to completion.

ROTO PEEN Scaler and VAC-PAC® System

Pentek's milling system, comprising the ROTO PEEN Scaler and the VAC-PAC® waste collection system, is a fully developed and commercialized technology. The primary application for the Pentek ROTO PEEN scaler is to remove coatings from concrete and steel floors, walls, ceilings, and structural components. It was designed to remove lead-based paints and radioactive and other hazardous contaminants from flat areas and large vertical surfaces, including the interface near walls and within confined spaces. The basic hand-held tool weighs 6.5 lbs, has a cutting width of two inches, is pneumatically driven, and works with a variety of interchangeable cutting media such as cutting wheels and 3M Heavy-Duty Roto Peen Flaps.

The Pentek ROTO PEEN Scalers removed paint coating from 650 square feet of concrete flooring in the demonstration area at an average rate of 40.6 ft^2/hr/scaler. Removal of the coatings from the concrete floor was sufficient to reduce the radiological levels from a fixed total beta/gamma contamination measuring 800 cm^2 (0.86 ft^2), with a maximum hot spot of 13,500 dpm/100 cm^2, to an elevated contamination area of only 200 cm^2 (0.22 ft^2), with the same hot spot reduced to 5,900 dpm/100 cm^2 fixed total beta/gamma. This technology is best used in confined areas and around and under obstacles, it is capable of removing coatings to within one-half inch from the edge of walls and obstructions.

The Pentek VAC-PAC® dust-collection system, which was connected to the ROTO PEEN Scaler tested, has the potential to significantly reduce the amount of airborne radioactivity during D&D activities and therefore potentially to reduce PPE requirements, especially respiratory protection.

Pegasus Coating Removal System

The Pegasus Coating Removal System (PCRS) is a chemical-based coating removal system developed by Pegasus International Inc. Four types of PCRSs are available for application to alkyds, latex paints, epoxies, urethanes, chlorinated rubbers, elastomers, mastics, and other chemical-resistant coatings. PCRS can be applied using long and short-handled spreaders, trowels, rollers or spray applicators. The material is left on the surface for a predetermined period of time (normally 3 to 72 hours) and allowed to interact with the coating. After the specified dwell time, the PCRS is removed using scrapers and/or large plastic shovels.

The PCRS was tested for its ability to decontaminate approximately 500 square feet of concrete flooring by removing the coating layer. The vendor applied the chemical, PCRS-1, to a one-foot by one-foot test patch on the floor of the demonstration area. Along with the PCRS-1, the two top layers of paint were easily removed after the four hours; however, the floor primer was not removed. The remainder of the test patch remained in place for an additional 48 hours before removing. The paint that was removed with the PCRS had re-dried on the floor and was removed with damp rags. After this time, the floor primer still could not be removed.

A second test patch was applied, this time covering the patch with a waxed paper to prevent drying of the PCRS. After 24 hours, the second test patch was removed with the same results; the floor primer was not removed. At this point the demonstration was ended.

Roto Peen with Captive Shot

Roto Peen uses centrifugal force to remove coatings and surface contamination from concrete floors. A series of 3M™ Heavy Duty Roto Peen flaps supporting tungsten carbide shot are mounted on a CPM-4 Concrete Planer provided by EDCO. The planer provides the correct rotational speed for the Roto Peen. The EDCO Concrete Planer is designed to remove paints and other surface contaminants from flat, horizontal areas. It has a cutting width of 5.5 inches and the depth of removal is determined by the rate of speed at which the unit is driven.

The Roto Peen with Captive Shot technology was able to remove paint coatings at a rate of 71 ft^2/hr with a two-person crew, and reduce contamination levels on the floor to background levels. The Roto Peen technology removed the floor's paint coatings with very little concomitant concrete removal. This resulted in minimal waste generation of 2.1 cubic feet of powder.

The vacuum system component of the Roto Peen technology performed sufficiently well to maintain airborne radioactivity levels in the area of the demonstration at background levels. In contrast, the baseline technology of scabbling has the potential for high levels of airborne contamination.

Remote Scabbler

The Pentek Inc. remotely operated scabbler, the Moose®, is designed to scarify large concrete floors and slabs in environments which require stringent control of airborne contamination and debris. The Moose® scabbler utilizes a single-step floor scarification process with three integral sub-systems: the scabbling head assembly, the on-board HEPA vacuum system, and the six-wheeled chassis. Remote operation is performed using a small control panel attached to the Moose® by up to 300-ft of tether. The scabbling head utilizes seven 2-1/4 inch diameter reciprocating scabbling bits, each 9-point tungsten carbide-tipped, which pulverizes the surface by delivering 1,200 hammer impacts/minute. Dust and debris are captured by the two-stage positive filtration HEPA vacuum system that deposits the waste directly into an on-board 23-gallon waste drum.

The Pentek Inc. Moose® successfully removed an average of 1/8 inch of concrete from the 620 square feet of flooring in the demonstration area, at a rate of 130 ft^2/hr for a crew of two persons, and within 7-8 in. from the union of the floor and the wall. Removal of concrete from the floor reduced the contamination levels in the demonstration from a maximum of 105,000 dpm/100 cm^2 total beta/gamma fixed contamination to a new maximum level of 3,500 dpm/100 cm^2, with the majority of the contamination at or below background levels after removal. Contamination found after the demonstration was located on moving pieces of the Moose® where there was exposed grease.

The Moose® was operated from a control panel outside of the demonstration area connected by a 50-ft tether, allowing the operator to work without wearing PPE such as tyveks or a respirator. However, due to the confined size of the demonstration area, a second operator wearing PPE, remained with the Moose® at all times to rearrange hoses. The Moose® was very maneuverable. Being only 26-inches wide, it passed through doorways and down hallways with few problems. Because of its ability to turn on its geometric center, the Moose® was able to turn corners and even enter a small elevator.

7.2.2 Comparison of Liquid Decontamination Technologies

One innovative technology for decontaminating liquids was demonstrated at CP-5 as part of the LSDP. For evaluation purposes, this technology was compared to the baseline technology of evaporation. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria. Comparison results are presented in Table 7.5.

Empore™ Membrane Separation Technology

The Empore™ membrane separation technology developed by 3M provides a method for enmeshing sorbent, surface-active particles in a web-like matrix, which is formed into a membrane. This membrane is designed to have the necessary integrity and handling strength for particle capture and has a high particle surface availability. To process water, the membrane is configured into a cartridge, which is then installed in commercially available filter housings. Sorbent particles can be placed in the membrane to selectively remove specific contaminants down to predetermined detection levels at high flow rates.

The key results of the demonstration were:

Flow Rate - 0.5 gpm using a 10-inch long cartridge
Total Volume Throughput - 4,500 gallons
Radiological Input - Cs-137 - approximately 0.60 pCi/ml; Co-60 - approximately 0.20 pCi/ml
Radiological Output - Cs-137 - approximately 0.003 pCi/ml; Co-60 - <0.02 pCi/ml (less than MDA)
Demonstration Duration - 150 hours
Total Waste - 0.56 cu ft. Low Level Radioactive Waste (LLRW)

Table 7.4 Comparison of Concrete and Coating Removal Decontamination Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Scabbling (Experiential Data)	Advanced Recyclable Media System (E&E Team)	Centrifugal Shot Blast (Concrete Cleaning Inc.)	Flashlamp (Parsons & Polygon)	ROTO PEEN Scaler and VAC-PAC® System (Pentek, Inc.)	Pegasus Coating Removal System (Pegasus, International))	Remote Scabbler (Pentek, Inc.)	Rotopeen with Captive Shot (3M)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • End point condition • Level of decontamination achieved • Proximity to corners/confined areas	• Concrete floor with painted coating • (Not demonstrated) • Paint coating and 1/4" concrete removed leaving a rough, bare concrete surface • Reduced to below background • 1"@ wall; cannot access tight spots	• Almost any surface material or geometry • 260 ft^2 of CP-5 floor • Paint coating removed plus some soft concrete patches, leaving a smooth bare concrete surface • Reduced to 4 hot spots, ranging from 4K-19K dpm/100 cm^2 • Reached against edges of walls and into corners	• Concrete floor with painted coating • 800 ft^2 of CP-5 service area floor • Paint coating removed leaving a smooth, bare concrete surface • Reduced to below background • 2"@ wall, 5"@ obstructions; cannot access tight spots	(The results of the demonstration were inconclusive. In some areas, coating was removed down to the concrete. However, in most areas, the bottom layer of coating turned to a black "soot-like" residue fixed to the concrete.)	• Concrete floor with painted coating • 650 ft^2 of CP-5 service area floor • Paint coating removed leaving a smooth, bare concrete surface • Hotspots reduced factor of $\cong$ 2 to 3; other areas reduced to below background • 1/2"@ wall; can fit into tight spots	(The results of the demonstration were inconclusive. The system did not work on primer coat during test patches, and the demonstration was ended.)	• Concrete floor with painted coating • 620 ft^2 of CP-5 service area floor • Paint coating removed leaving a rough, but even, bare concrete surface • All but 1 hot spot reduced to below background. One hot spot reduced from 105K to 3.5K dpm/100 cm^2 • 6" @ wall	• Concrete floor with painted coating • 425 ft^2 of CP-5 service area floor • Dust-free uniform surface • Hotspot reduced factor of $\cong$ 4; other areas reduced to below background • 1"-2" @ obstructions; cannot fit into tight areas
2. Safety	• Hazards • Cross-contamination • Safety features	• Flying concrete pieces present eye hazard; high speed moving parts • Airborne activity is generated (up to 10% of debris) • None	• 100 dBA noise at blast head, hoses present trip hazard, projectile hazard, dust inside tent • No airborne activity outside tent • Dead-man switch on blast nozzle	• Shot presents slipping and projectile hazard; hoses present trip hazard • No airborne radioactivity generated • Dead-man switch		• Hoses present trip hazard; Rotating & cutting hazards • No airborne radioactivity generated because of integral vacuum system • None		• Hoses present trip hazard, noise, Impact and heavy equipment operation • No visible dust during demo; airborne activity at or below background • Full drum alarm light	• Heavy equipment operation; noise • No visible dust during demo; airborne activity at or below background • Auto shutoff if vacuum drops
3. Cost	• Product vs. service • Rental vs. purchase • Cost comparison • Consumable items	• Either • Rental • High costs for erection of temporary enclosure and cleanup of debris • Scabbler pistons	• Service provider only • Rental • Slightly more expensive than baseline • Some media, filters	• Service provider only • Not applicable • Less expensive than baseline • Shot, filters		• Either (demo: service provider) • Purchase • Less expensive than baseline • Flaps, HEPA and roughing filters		• Either (demo: service provider) • Rental or purchase • More expensive than baseline • Filters, hoses	• Product • Purchase • Less expensive than baseline • Flaps, filters, hoses
4. Speed and Responsiveness	• Production rate • Cutting width • Depth of removal	• 200 ft^2/hr • (ANL-E) • 1/4" to 1/2"	• 41.9 ft^2/hr • N/A • Surface coating	• 310 ft^2/hr • 13 inches • ½" (up to 1" with other units)		• 40.6 ft^2/hr/unit • 2 inches • Coating only		• 130 ft^2/hr • 14" • ¼", 1/8" avg.	• 71 ft^2/hr/unit • 5.5 inches • 1/16"
5. Waste Generation	• Primary (type & amount) • Secondary (type & amount other than PPE) • Integration with radwaste system	• Paint/concrete chips & powder: 24 ft^3 • Tent enclosure, worn pistons • None; manual cleanup required	• Powdery mix of media and paint chips: 0.8 cu.ft. • HEPA filter, loose filter material, 600 ft^2/hr tenting material, rags • Integral system separates reusable material from radwaste	• Powdery mix of paint, concrete, shot: 2.5 ft^3 • Spent shot, filters, hoses • Waste collected by integral vacuum system and directly deposited into drums		• Powdery paint chips: 2.5 ft^3 • Flaps, filters, hoses • Waste contained by integral vacuum system and deposited directly into sealed drums		• Mix of powder and small pieces of paint and concrete, 17 cu.ft. • Filters, 4 ft. vacuum hose, rags • Waste collected by integral vacuum system and directly deposited into drums	• Powdery mix of paint & concrete: 2.1 ft^3 • Flaps, filters, hoses, rags • Waste collected by integral vacuum system and directly deposited into drums
6. Readiness Status	• Commercial availability • Proprietary/patent issues	• Commercially available • None	• Commercially available • Patented system	• Commercially available • Patent pending on proprietary modifications		• Commercially available • None		• Commercially available • None	• Components commercially available • None
7. Support Requirements	• Minimum crew size • Utilities • Facility modifications	• Three people (excluding HP) • (ANL-E) • Need to erect enclosure for high contamination areas	• Three people (excluding HP) • Electrical: 110 VAC; compressed air: 250 cfm • Temporary tents	• One person (excluding HP) • Electrical: 480 VAC, 3-phase, 60 amps • 4' herculite wall constructed to contain shot		• One person (excluding HP) • Compressed air: 750 cfm; Electrical: 115 VAC, 20 amps • None		• Two people • Electrical: 110 VAC, Compressed air: 375 cfm • None	• Two people • Planer: 208 VAC @ 30 amps, single phase; Vacuum 110 VAC @ 15 amps and compressed air (300 scfm @ 100 psig) • None
8. Mobilization & Demobilization	• Transportability • Size/portability • Setup time • Need for & ease of decontamination • Breakdown requirements	• Truck or van • 24"x30"x48"/ 200 lb. • 4 hours • Decontamination can take 2-8 hours • Sweep/vacuum debris; remove temporary enclosure	• Truck • 32"x32"x60"/450 lbs. Plus 36" circularx60"/600 lbs. • 8.5 hours • Decontamination took 2.2 hour • Shovel/sweep debris, remove tent	• Truck • Blaster: 17"x43"x50"/ 650 lb. Vacuum: 27"x60"x113"/ 700 lb. • 16 hours (problems with HEPA filter) • Decontamination took 7 hours • Sweep/vacuum excess shot left on floor		• Back of pickup truck • Scaler: 3"x4"x6"/ 7 lb.; Vacuum: 28"x48"x72"/ 750 lb. • 4 hours • No decontamination was required • None		• Truck • 66"x29"x74"/1,650 lb. • 3.5 hours • Filter removal, vacuum inside system, wipe down • None	• Truck • Planer: 180 lbs; 20"x40"x36"; Vacuum: 750 lbs; 28"x48"x72" • Minimal (< 1 hour) • Wet wipes used to clean dust (took 3 person-hours) • None
9. Ergonomics	• Ease of use • Worker comfort • Noise • On-site training /skill level • Independence	• Walk behind push model for floor areas • Vibrations can cause operator fatigue • 84 dBa • 2 hours per person • Constant hands-on operation	• Light weight blast nozzle • Operator seated during operation • 100 dBa • 2 hr./person • Constant, hands-on operation	• Walk-behind floor model • Self-propelled unit reduces operator fatigue • 97 dBa • None: Operated by vendor personnel • Constant hands-on operation		• Hand-held scaler unit • Operators work on hands and knees for floor areas; may eliminate the need for respirators • 94 dBa • Minimal • Constant hands-on operation		• Easy to use, remote control • Good • 106 dBa • N/A • Constant hands-on operation	• Easy-to-use walk-behind model • Good • 100 dBA • Minimal (< 1 hour) • Constant hands-on operation

Table 7.4 (cont) Comparison of Concrete and Coating Removal Decontamination Technology Demonstrations

Performance Attribute	Evaluation Criteria	ROTO PEEN Scaler and VAC-PAC® System (Pentek, Inc.)	Pegasus Coating Removal System (Pegasus, International))	Remote Scabbler (Pentek, Inc.)	Rotopeen with Captive Shot (3M)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • End point condition • Level of decontamination achieved • Proximity to corners/confined areas	• Concrete floor with painted coating • 650 ft^2 of CP-5 service area floor • Paint coating removed leaving a smooth, bare concrete surface • Hotspots reduced factor of ≅ 2 to 3; other areas reduced to below background • 1/2"@ wall; can fit into tight spots	(The results of the demonstration were inconclusive. The system did not work on primer coat during test patches, and the demonstration was ended.)	• Concrete floor with painted coating • 620 ft^2 of CP-5 service area floor • Paint coating removed leaving a rough, but even, bare concrete surface • All but 1 hot spot reduced to below background. One hot spot reduced from 105K to 3.5K dpm/100 cm^2 • 6" @ wall	• Concrete floor with painted coating • 425 ft^2 of CP-5 service area floor • Dust-free uniform surface • Hotspot reduced factor of ≅ 4; other areas reduced to below background • 1"-2" @ obstructions; cannot fit into tight areas
2. Safety	• Hazards • Cross-contamination • Safety features	• Hoses present trip hazard; Rotating & cutting hazards • No airborne radioactivity generated because of integral vacuum system • None		• Hoses present trip hazard, noise, Impact and heavy equipment operation • No visible dust during demo; airborne activity at or below background • Full drum alarm light	• Heavy equipment operation; noise • No visible dust during demo; airborne activity at or below background • Auto shutoff if vacuum drops
3. Cost	• Product vs. service • Rental vs. purchase • Cost comparison • Consumable items	• Either (demo: service provider) • Purchase • Less expensive than baseline • Flaps, HEPA and roughing filters		• Either (demo: service provider) • Rental or purchase • More expensive than baseline • Filters, hoses	• Product • Purchase • Less expensive than baseline • Flaps, filters, hoses
4. Speed and Responsiveness	• Production rate • Cutting width • Depth of removal	• 40.6 ft^2/hr/unit • 2 inches • Coating only		• 130 ft^2/hr • 14" • ¼", 1/8" avg.	• 71 ft^2/hr/unit • 5.5 inches • 1/16"
5. Waste Generation	• Primary (type & amount) • Secondary (type & amount other than PPE) • Integration with radwaste system	• Powdery paint chips: 2.5 ft^3 • Flaps, filters, hoses • Waste contained by integral vacuum system and deposited directly into sealed drums		• Mix of powder and small pieces of paint and concrete, 17 cu.ft. • Filters, 4 ft. vacuum hose, rags • Waste collected by integral vacuum system and directly deposited into drums	• Powdery mix of paint & concrete: 2.1 ft^3 • Flaps, filters, hoses, rags • Waste collected by integral vacuum system and directly deposited into drums
6. Readiness Status	• Commercial availability • Proprietary/patent issues	• Commercially available • None		• Commercially available • None	• Components commercially available • None
7. Support Requirements	• Minimum crew size • Utilities • Facility modifications	• One person (excluding HP) • Compressed air: 750 cfm; Electrical: 115 VAC, 20 amps • None		• Two people • Electrical: 110 VAC, Compressed air: 375 cfm • None	• Two people • Planer: 208 VAC @ 30 amps, single phase; Vacuum 110 VAC @ 15 amps and compressed air (300 scfm @ 100 psig) • None
8. Mobilization & Demobilization	• Transportability • Size/portability • Setup time • Need for & ease of decontamination • Breakdown requirements	• Back of pickup truck • Scaler: 3"x4"x6"/ 7 lb.; Vacuum: 28"x48"x72"/ 750 lb. • 4 hours • No decontamination was required • None		• Truck • 66"x29"x74"/1,650 lb. • 3.5 hours • Filter removal, vacuum inside system, wipe down • None	• Truck • Planer: 180lbs; 20"x40"x36"; Vacuum: 750 lbs; 28"x48"x72" • Minimal (< 1 hour) • Wet wipes used to clean dust (took 3 person-hours) • None
9. Ergonomics	• Ease of use • Worker comfort • Noise • On-site training /skill level • Independence	• Hand-held scaler unit • Operators work on hands and knees for floor areas; may eliminate the need for respirators • 94 dBa • Minimal • Constant hands-on operation		• Easy to use, remote control • Good • 106 dBa • N/A • Constant hands-on operation	• Easy-to-use walk-behind model • Good • 100 dBA • Minimal (< 1 hour) • Constant hands-on operation

Table 7.5 Comparison of Liquid Decontamination Technologies

Performance Attribute	Evaluation Criteria	Baseline: Evaporation	Empore (3M)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • End point condition • Level of decontamination achieved	• Radioactively contaminated water • (Not concurrently demonstrated) • Meets regulatory requirements for release as wastewater • Reduced to at or below release criteria	• Radioactively contaminated water • CP-5 storage pool • Cs-137, Co-60 at or below release criteria • Cs-137 to 0.003 pCi/ml and Co-60 to <MDA
2. Safety	• Hazards • Cross-contamination • Safety features	• Pumping and transporting • Leak/spill potential during pumping and transport • Standard large facility operations and maintenance (O&M)	• Minimal • Leak potential during pumping • N/A, prototype
3. Cost	• Product vs. service • Rental vs. purchase • Cost comparison • Consumable items	• Both • Both • High first cost for design and construction • Standard large facility O&M items	• N/A, prototype • N/A, prototype • ~50% of baseline • Cartridges and sorbent material
4. Speed and Responsiveness	• Production rate	• 700 gal./day for 24 hr./day operation (~0.5 gpm)	• 0.5 gpm at prototype scale
5. Waste Generation	• Primary (type & amount) • Secondary (type & amount other than PPE) • Integration with radwaste system	• ~1 cu.ft. low-level radwaste (LLRW)/24Kgal. liquid • None • Residue sent to LLRW disposal	• 0.56 cu.ft. LLRW/4.5Kgal. • ~40 cu.ft. of equipment • Cartridges sent to LLRW disposal
6. Readiness Status	• Commercial availability • Proprietary/patent issues	• Commercially available • None	• Prototype scale only • Patented by 3M
7. Support Requirements	• Minimum crew size • Utilities • Facility modifications	• Pump/transport: 2; Evaporator: 2 • Standard large facility utilities • N/A	• One for periodic surveillance and filter changing • 110 VAC • None
8. Mobilization & Demobilization	• Transportability • Size/portability • Setup time • Need for & ease of decontamination • Breakdown requirements	• Transport liquid to large, fixed facility • Large, fixed facility • 45 hours to transport 24Kgal. • Decontaminate pumps, tanks, hoses • None	• Truck • Prototype equipment footprint: 14'x3'x3.5' high/~250 lb. • 8 hours • Not demonstrated, equipment could be reused or disposed of as radwaste • As above
9. Ergonomics	• Ease of use • Worker comfort • On-site training /skill level • Independence	• Standard large facility O&M • Good • Standard large facility O&M • Constant attention during pumping, transport, and evaporation	• Very easy • Good • 15 minutes • Relatively independent operation

7.3 Dismantlement Technologies

Improvements in robotics and technologies associated with remote dismantlement and other operations are critical for the future decontamination and decommissioning market.

Many operations associated with D&D cannot be performed without some sort of remote capabilities. And, as concern for worker health and safety issues continues to grow, the number and types of activities to be performed using robotics and remotely deployed methodologies are expected to grow substantially. The need for multi-purpose, omni-use machines to perform complicated evolutions in highly radioactive and hazardous environments is expected to increase dramatically as the pressure to decrease exposure to workers continues.

To some extent, robotics technologies can be considered enabling technologies. For many tasks and activities associated with the D&D of the DOE weapons complex, no remediation alternatives are currently available.

One major problem to be faced by D&D robotics developers is the relatively small amount of repetitive work to be accomplished through remote means. Unlike typical assembly line robotics systems, D&D work is rarely repeatable and programmable. Therefore, interface systems between remote operators and machines in the field will continue to require improvement and refinement to be economically competitive with current manual labor methods.

7.3.1 Comparison of Improved Tools Technologies

One innovative technology for an improved tool was demonstrated at CP-5 as part of the LSDP. For evaluation purposes, this technology was compared to the baseline technology of the standard tool. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria. Comparison results are presented in Table 7.6.

Swing Free Crane

The swing-reduced crane control system is designed to minimize the swinging induced in loads being moved by a crane and to enhance the operator's ability to control the remote positioning of loads. The technology employs a No-Sway™ crane controller manufactured by Convolve Inc., with newly developed AC motors known as AC flux vector control motors or vector drives. These motors allow a programmable logic controller (PLC) to control motor speed and acceleration. The No-Sway™ crane controller uses a solid-state PLC to control the motion of the crane bridge or trolley in order to minimize the degree a load will swing when it is being moved by a crane. This permits the operator to move the crane in precise steps without causing the swinging of the load.

The swing-reduced crane control technology is applicable to a wide range of cranes and gantries. It can be either built into new systems or retrofitted onto older systems; however, the basic technology has much broader applicability. It can be used on robotics arms or through-the-wall manipulators to enhance the operator's ability to control these systems. It could also be applied to machine tools, either manually or pneumatically controlled. In short, it could be employed on any system that has to accelerate or decelerate and is expected to be accurately positioned. For the CP-5 project application, the passive swing-reducing technology reduced the swing time 60% or more.

7.3.2 Comparison of Robotics Technologies

Two innovative technologies for robotics were demonstrated at CP-5 as part of the LSDP. For evaluation purposes, these technologies were compared to the baseline technology of manual entry and tool handling. The technologies were compared in nine broad categories of performance attributes, each including specific evaluation criteria. Comparison results are presented in Table 7.7.

Dual Arm Work Platform

The demonstration focused on the use of the Dual Arm Work Platform (DAWP), produced by the DOE Robotics Technology Program, to dismantle the CP-5 reactor vessel and surrounding graphite moderator, and on miscellaneous tasks best suited for the use of tele-operated robotics. It manipulated standard tools (saws, jackhammers, etc.) with two Schilling Titan III hydraulically controlled robot arms with grips, which were tele-operated from a remote control location. The arms provide six degrees of freedom and are powered by a 3,000 psi hydraulic system. Each arm is capable of lifting 240 lbs. The grippers on the arms are capable of exerting a 1,000-lb. crushing force and a rotational torque of 75 lb-ft. At the CP-5 reactor site, the two arms were connected by a work platform, with which the computerized controls formed the DAWP.

Operators would use the DAWP in conjunction with Rosie, a tethered, 50-m (165 foot) long, robotic system controlled via tele-operation from a control console located outside of the radiological containment area, to off-load radioactive materials. Aluminum, boral, graphite, and miscellaneous LLRW were size-reduced by the DAWP and placed into a steel drum or transfer can attached to Rosie, which would move the can to a staging area for manual packaging.

The DAWP system is not a commercially available product at this time. The CP-5 implementation was its first application. The demonstration of the DAWP was to determine areas for improvement in order to make this technology commercially viable. During the demonstration, the DAWP performed the following: removed 3,000 lbs. of graphite blocks, 1,400 lbs. of lead sheeting, 620 lbs. of boral, 2,000 lbs. of carbon steel; untorqued and removed 38 carbon steel studs; size-reduced and dismantled a significant portion of the aluminum reactor tank (following approximately 200 linear feet of cuts through 3/8” - 3/4” aluminum plating), and removed the resultant 400 lbs. of aluminum plate from the reactor tank assembly.

Rosie Remote Work System

RedZone Robotics’ Rosie system performs mechanical dismantlement of radiologically contaminated structures by remotely deploying other tools or systems. Rosie contains a mobile platform used to support reactor assembly demolition through its long reach, heavy-lift capability and deployment and positioning of a Kraft Predator dexterous manipulator arm. Personnel with little or no robotics experience can be adequately trained to safely and efficiently operate this sophisticated robotics system in a relatively short time period.

The Rosie system, with the Kraft Predator arm attached, removed approximately 500 lbs. of graphite blocks without exposing personnel to radioactivity. Using the steel transfer can, Rosie safely off-loaded a total of 8,450 lbs. of radioactive materials including graphite blocks, lead sheeting, boral, and aluminum plate from the top of the reactor assembly with radiation levels up to 1.2 R/hr. With the high reach capability of the heavy manipulator-mounted cameras, Rosie provided useful, supplemental viewpoints to the DAWP operators when unique camera angles were needed to support reactor tank and graphite removal operations. The instrumented lifting hook on Rosie’s boom was able to remotely move dismantled graphite blocks from the top of the reactor structure (3 to 4.5 meters (10 to 15 feet) high) to a nearby packaging and disposal area at floor level.

Remote Control Concrete Demolition System

The Brokk BM 150, manufactured by Holmhed

Systems AB of Sweden and supplied by Duane Equipment Corp., uses a remote operated articulated hydraulic boom with various tool head attachments. The machine is designed primarily to drive a hammer and has a reach of fifteen feet. The Brokk can be operated by someone 400 feet away or in a different room with a TV monitor, up to a 30 degree gradient. The unit requires a 480 volt, 50 amp circuit for its power source. Two attachments were used in this demonstration; the hydraulic hammer and the excavating bucket. The hammer operates at 600 foot-pounds and has outputs of 1,000 to 1,500 beats per minute. The bucket has a capacity of 1/4 cubic yard and has a smooth cutting edge.

Table 7.6 Comparison of Improved Tools Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Standard Crane (Experiential Data)	Swing Reduction Crane (DOE Robotics Technology Development Program)
1. Effectiveness and Quality of Results	• Applicability • Demonstration area • Reliability/validity	• Lifting loads and deploying remotely operated equipment • Polar crane at CP-5 • Crane operated reliably since 1954	• Lifting loads and deploying remotely operated equipment plus robotics arms or manipulators • Polar crane at CP-5 • Reliable over 1 year
2. Safety	• Hazardous work conditions • Cross-contamination • Need for worker protection	• Standard industrial operations • Potential from damage to hazardous loads • N/A	• Standard industrial operations • Less than baseline • N/A
3. Cost	• Product vs. service • Rental vs. purchase • Cost	• Product • Purchase • No additional costs	• Product • Purchase • Minimal additional cost if done as part of a needed motor replacement. High cost if replacing good motors
4. Speed and Responsiveness	• Impact on operator speed and efficiency	• Swing time slows down even highly skilled operators	• Swing time reduced by 60% or more
5. Waste Generation	• Potential	• Waste generation potential from damaging either the load or other equipment	• Potential less than baseline through increased operator efficiency
6. Readiness Status	• Commercial availability • Field-tested • Proprietary	• Commercially available • Used in industry for decades • No	• Commercially available • Tested at Oak Ridge, Savannah River, Sandia National Labs • Individual components, yes
7. Support Requirements	• Utilities • Personnel • Facility modifications • Required reviews	• Standard electrical • One • None • None	• Standard electrical • One • Crane motor replacements • Standard crane recertification
8. Mobilization & Demobilization	• Transportation • Size/portability • Setup time	• Baseline is standard, permanently installed polar crane • See above • See above	• Replacement motors, controls by truck or van • Easily portable • Several days including recertification
9. Ergonomics	• Ease of use • Worker comfort • On-site training/skill level • Independence	• Requires skilled operator • Good • Standard crane operator training • Constant hands-on operation	• Reduces skill level required for equivalent operation • Good • Additional training required for skilled operator • Constant hands-on operation

Table 7.7 Comparison of Robotics Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: Manual Entry & Tool Handling (Experiential Data)	Dual Arm Work Platform (DOE Robotics Technology Development Program: ORNL,INEL, & SNL)	Remote Controlled Concrete Demolition System (Brokk, Holmhed Systems AB, and Duane Equipment Corporation)	Rosie Remote Work System (RedZone Robotics)
1. Effectiveness and Quality of Results	• Applicability • Flexibility of use • Deployment means • Minimum dimensions • Maximum reach • Grasp size	• Radioactive and hazardous material handling, cutting, lifting • Limitations to long-handled tool capabilities • Manual • Tool-specific • Tool-specific • Tool-specific	• Radioactive and hazardous material handling, cutting, lifting • Very broad range of tools • Placed by crane, operable by tether from 250 ft. without direct line of sight • Prototype, ~2m x 1m x 2m high • 78", plus reach of tool • 6" grasp	• Demolition of radioactively contaminated concrete • Very broad range of tools • Self-propelled • 44"x92"x49" high • 15' • N/A	• Radioactive and hazardous material handling, cutting, lifting • Very broad range of tools • Tethered locomotor operable from 100m without direct line of sight • 86"x122"x42" high • 8m vertical, 4m horizontal • Tool specific
2. Safety	• Hazardous work conditions • Cross-contamination • Worker protection	• High radiation area; confined space; high airborne activity • Possible tracking of contamination by workers leaving work area • Protective clothing, respirators	• Much less than baseline • Less than baseline due to fewer personnel incursions into work area • Depends on remote control site conditions	• Much less than baseline • Less than baseline due to fewer personnel incursions into work area • Depends on remote control site conditions	• Much less than baseline • Less than baseline due to fewer personnel incursions into work area • Depends on remote control site conditions
3. Cost	• Product vs. service • Rental vs. purchase • Cost comparison • Consumable items	• Products • Both, tool-specific • Relatively high cost due to personnel exposure limits • Standard radiation area operational items	• N/A, prototype • N/A, prototype • Direct cost is tool and task-specific, significant indirect savings from reduced personnel exposures • Standard radiation area operational items	• Both • Both • ~6% of baseline • Standard radiation area operational items	• Product • N/A, full-scale prototype • Direct cost is tool and task-specific, significant indirect savings from reduced personnel exposures • Standard radiation area operational items
4. Speed and Responsiveness	• Rate of dismantlement	• Rate is based on manual operation and is tool-specific; dismantlement work times are limited by personnel exposure limits	• Some tools/tasks were faster and some slower than baseline, but all were significantly safer	• 66 cu.yd. of reinforced concrete demolished, segregated, and loaded into shipping containers in 16 days (rate is ~19 times faster than baseline)	• Some tools/tasks were faster and some slower than baseline, but all were significantly safer
5. Waste Generation	• Type (other than PPE) • Volume	• None specific to the tools • N/A	• None specific to the platform • N/A	• None specific to robot • N/A	• None specific to the robot • N/A
6. Readiness Status	• Commercial availability • Field-tested • Proprietary	• Most tools are commercially available; custom tools may be required for certain tasks • Extensive field testing • No	• First application of platform, but tools commercially available • See above • No	• Commercially available • Yes • Yes	• First full scale application of robot, but tools commercially available • See above • No
7. Support Requirements	• Facility modifications • Personnel • Utilities • Regulatory reviews	• Temporary shielding to protect workers • Tool-specific • Tool-specific • Tool-specific	• None • One • 110/220 VAC, 12/24 VDC • None specific to platform	• None • One • 480 VAC, 50A • None specific to robot	• None • One • 480 VAC, 125 A. • None specific to the robot
8. Mobilization & Demobilization	• Transportation • Weight • Set-up time • Need for and ease of decontamination	• Skilled workers and specialty tools may be required from off-site sources • Tool-specific • Frequent interruptions and loss of efficiency because of limited stay times in high radiation areas • Workers and tools must be decontaminated	• Heavy truck • ~5,000 lb. • Significant • Onboard components sealed, allowing pressurized washdown, but some parts removal needed for free release	• Heavy truck • 3,086 lb. Without attachments • Minimal • Robot and all attachments were decontaminated and free released	• Heavy truck • 8,600 lb. • Tool specific • Onboard components sealed, allowing pressurized washdown, but some parts removal needed for free release
9. Ergonomics	• Training requirements • Ease of use • Worker comfort	• Standard radiation training • Long-handled tools difficult to use • Comfort reduced by PPE and respirators	• Training of 4 operators plus one supervisor required ~200 hrs. cumulative operating time • Good • Very good	• Unknown, operated by contractor personnel • Good • Very good	• Training of 4 operators plus one supervisor required ~200 hrs. cumulative operating time • Good • Very good

7.4 Worker Health and Safety

Two innovative technologies for personal protective clothing were demonstrated at CP-5 as part of the LSDP: the FRHAM-TEX Cool Suit and NuFab™ Anti-Contamination Suit. For evaluation purposes, these technologies were compared to the baseline technology of one Tyvek® suit. The comparison of these technologies with the Tyvek® was difficult due to their relative differences. Both suits tested were waterproof while the Tyvek® suit is not. This leads to the innovative suits providing increased radiological protection at the expense of decreased discomfort. Comparison included nine broad categories of performance attributes, each comprised of specific evaluation criteria.

Protective clothing performance was determined from questionnaires provided to workers who donned the suits. The results of the demonstration are therefore subjective rather than qualitative. Comparisons are presented in Table 7.8.

*FRHAM-TEX Cool Suit*Ô

The FRHAM-TEX Cool Suit™, manufactured by FRHAM Safety Products, is a one-piece, disposable coverall with a single front zip-lock closure. It is constructed of a spun bonded polyester bonded to a butylene/polyhydrophilic film to make the suit breathable and waterproof. The material is designed to allow moisture generated inside the suit to be transmitted to the outside. A proprietary process used to heat-seal the seams of the suit during manufacturing strengthens the integrity of the suit.

The FRHAM-TEX suits have very strong seams that did not rip while donning or doffing or during heavy work with the jackhammer. Made of a strong material that does not tear as easily as the baseline Tyvek®, the suits also were much hotter than the Tyvek® suit. However, the baseline suit was not waterproof and did not provide the same level of protection as the FRHAM-TEX. Workers noted pools of sweat in their respirators and gloves after working in the FRHAM-TEX suits. The FRHAM-TEX suits were easier to don than the baseline, were roomier and allowed ease of movement during work activities.

*NuFab*Ô *Anti-Contamination Suit*

The NuFab™ Anti-Contamination Suit, manufactured by Kappler USA, is comparable to the FRHAM-TEX. It is a one-piece, disposable coverall with a single front zipper. It is constructed of a spun bonded polypropylene and microporous film layers to make the suit breathable and waterproof. The material is designed to allow moisture generated inside the suit to be transmitted to the outside. A proprietary process used to heat-seal the seams of the suit during manufacturing strengthens the integrity of the suit.

The NuFab™ suits were roomier and allowed ease of movement during work activities, but were much hotter than the baseline Tyvek® suit. However, the baseline suit was not waterproof and did not provide the same level of protection as the NuFab™. Workers noted pools of sweat in their respirators and gloves after working with the NuFab.™ More comfortable to the skin than the baseline suit, NuFab™ was more difficult to don due to the liner of the suit sticking together. The suits tended to rip easier than the baseline suit, especially where the legs joined the booties.

Table 7.8 Comparison of Protective Clothing Technology Demonstrations

Performance Attribute	Evaluation Criteria	Baseline: One Tyvek® Suit (Experimental Data)	FRHAM-TEX Cool Suit (FRHAM Safety Products)	NU-FABÔ Suit (Kappler USA)
1. Effectiveness and Quality of Results	• Degree of protection • Physical integrity	• Rips and tears easily. Multiple layers are required for a greater degree of protection • Sewn seams. Saranex coating is used to waterproof suit	• Made of strong material that does not tear as easily when snagged. • Heat-sealed seams to waterproof the suit	• Tears where bootie and leg meet • Heat-sealed seams to waterproof the suit
2. Speed and Responsiveness	• Impediments to worker mobility or work process	• No noticeable impediments. Heat generation can cause a decrease in productivity.	• Roomy and allowed ease of movement. Large heat generation can cause a decrease in productivity.	• Roomy and allowed ease of movement. Large heat generation can cause a decrease in productivity.
3. Safety	• Distractions • Vision impairment • Dexterity • Communications	• No distractions • No visual impairment • No impairment to dexterity • Able to communicate	• No distractions • No visual impairment • Roominess of suit allows good dexterity • Able to communicate	• No distractions • No visual impairments • Roominess of suit allows good dexterity • Able to communicate
4. Mobilization & Demobilization	• Ease of donning • Ease of doffing	• Standard • Standard	• Standard • Standard	• Inside of suit stuck together which caused difficulty donning. • Standard
5. Support Requirements	• Assistance required • Additional material requirements	• No assistance required to don/doff. • No additional material required	• No assistance required to don/doff • No additional material required	• No assistance required to don/doff • No additional material required
6. Ergonomics	• Fit and adjustability • Comfort: temperature, humidity, skin sensation	• Available in various sizes • Increases body heat	• Available in various sizes • Hotter than baseline suit	• Available in various sizes • Hotter than baseline suit. Comfortable to the skin
7. Waste Generation	• Weight of one full set • Compactability	• Negligible • Good volume reduction capabilities	• Negligible • Good volume reduction capabilities	• Negligible • Good volume reduction capabilities
8. Readiness Status	• Commercial availability • Future improvements	• Readily available • Waterproofing without the need of coatings	• Readily available • Need to improve on heat transfer to exterior	• Readily available • Need to improve on heat transfer to exterior and on durability of seems where booties and leg meet
9. Cost	• Ability to reuse • Cost comparison	• Disposable • $4.50/suit	• Disposable suits were tested; however, reusable/washable suites are available. • $33.18/disposable suit (average)	• Disposable suits were tested; however, reusable/washable suites are available. • $30.19/disposable suit (average)

8.0 COMMUNICATIONS

The CP-5 LSDP utilized a spectrum of communication approaches, vehicles and systems to provide effective interaction between project participants and the interested community. These vehicles included formal DOE reporting systems and notification processes, industry conferences and forums, industry and DOE Complex reviews, integration and communication with Site Technology Coordination Groups (STCG), other LSDPs, other focus areas and an Internet Home Page.

The following discussions on electronic communications and industry, conference and forum participation provide perspective on project communication activities.

8.1 Background

The DOE FETC has the responsibility for implementing the DDFA, to include the planning, monitoring, and evaluation of projects to meet the requirements of EM-50 and customer organizations of Environmental Management-Office of Waste Management (EM-30), EM-40, and Environmental Management-Office of Nuclear Materials and Facilities Stabilization (EM-60). The DDFA authorization of the CP-5 LSDP provided an opportunity to compare the attributes of innovative and baseline D&D technologies, to demonstrate technologies at a scale resulting in meaningful cost and performance information to potential end-users, and ultimately to communicate decommissioning related information to other host sites. Within the CP-5 LSDP, a communication plan was prepared to describe methods and protocols to receive and incorporate appropriate input from EM/DDFA stakeholder organizations, and to transfer project performance and technology information through multiple pathways to facilitate ultimate application and benefit.

Communicating the experience gained through the CP-5 LSDP was an important project goal, and was integral to activities performed by all personnel. The CP-5 LSDP Communication Plan described the site technical problem, the lead project communicators, the stakeholders, and communication methods. The methods used by the CP-5 LSDP included the following:

- DOE reporting system reports
- Industry conferences
- DOE sponsored meetings and reviews
- Project technology brokering activities
- Participation in Site Technology Coordination Groups (STCGs)
- Communication with other LSDPs
- The Strategic Alliance's internet home page
- Teleconferences with DOE sites
- Technology Demonstration Summary Sheets (1 Pager)
- Innovative Technology Summary Reports
- Final Report
- General public participation through the D&D subgroup of the Community Leaders Network

8.2 Electronic Communications

A unique and primary communication method involved the interaction between the companies, which made up the SA and their counterparts involved in federal and commercial D&D projects. Communication was focused on internal project communications to facilitate management and performance interaction and external outreach to public and stakeholder groups to publicize project performance. SA members participated both internally and externally in technology demonstration communications using an Internet Web site.

The Internet Web Site was developed and maintained to facilitate effective communications among the geographically dispersed members of the SA, DOE, and others with public access to project information via the Internet and World Wide Web (Web). This communication tool used both Internet/Web and proprietary information protocols to share information and provide security with multiple access privilege levels. A Lotus Notes™ dynamic object-store database was used to store and disseminate the wide range of D&D information types via the Web and Lotus Notes™, using a single Lotus Notes™ server. Multiple levels of Web and Lotus Notes™ security facilitated categorized information access such as:

- Internal SA communication and program management activities
- Operational activities
- Information exchange and communication with other DOE sites, non-Alliance companies, organizations and others, including the general public.

The "Strategic Alliance for Environmental Restoration" Web Site presented CP-5 LSDP information by section, utilizing a button format, and included:

- Overview (project management and overview)
- Tech Transfer (technology identification and selection)
- Demonstration Projects (demonstration fact sheets and evaluations)
- Web Links (access to free Web resources)
- Guest Book (sign in)
- SA Members (Alliance Member-Only Area)
- Public Discussion (technology communications-public/private and E-mail)

The Strategic Alliance Member Only area provided a secured area on the Web site for the performance of various SA-internal operational activities. The Technology Transfer page segmented D&D technologies into various categories by demonstration and technology type. The Demonstration Projects page provided a hierarchical environment for projects of interest. Public discussion was facilitated by the Public Discussion Forum Entry page, which provided various interactive discussion areas for information exchange, technology discussion and other public forum opportunities.

In addition to the CP-5 LSDP-specific Web Site, project information is included on the DOE-CH, STCG, FETC, EM-50 and EM Home Pages. The CP-5 LSDP Web Site will be permanently linked to the DDFA Web Site at http://www.wpi.org/doe/focus/dd at the conclusion of the CP-5 LSDP.

8.3 Industry Conferences and Forums

Presentation and collection of CP-5 LSDP information at conferences and forums provided valuable information exchange among problem holders, contractors, regulators, and industry representatives. Conferences and forums included:

- National Decommissioning meetings
- Technical Information Exchange Workshops
- Mid-year and annual project reviews
- FETC-sponsored Technology Information Workshops
- CP-5 LSDP Open Houses
- American Nuclear Society meetings
- National STCG meetings
- Annual waste management conferences
- Industry conferences on nuclear issues (D&D, regulatory, cost estimating and standards, international technology application, etc.)
- Spectrum Conference

Various nuclear utility forums and meetings:

- 1995 FETC D&D Workshop, Morgantown, WV
- 1995 Industry Leaders Forum, Amelia Island, FL
- 1995 D&D Decision Makers Forum, Lansdowne, MD
- 1996 FETC D&D Workshop, Morgantown, WV
- 1996 American Nuclear Society D&D Regional Meeting, Chicago,
- 1996 Environmental Research Colloquium, Phoenix, AZ

- 1996 Spectrum Conference
- National Decommissioning Committee meetings
- Technical Information Exchange (TIE) meetings and workshops
- Site Technology Coordination Group meetings
- FETC-sponsored LSDP Information Exchange meetings
- 1996 Mid-Year Review, FETC, Morgantown, WV
- 1997 ASME Peer Review, FETC, Morgantown, WV
- 1997 DDFA Program Review, FETC, Morgantown, WV
- 1998 Mid-Year Review, FETC, Morgantown, WV
- 1998 Lessons Learned Meeting, FETC, Morgantown, WV

The SA participated in information exchanges with two other ongoing LSDPs, and with the Site Technology Coordination Groups across the DOE Complex to refer successful technologies to other problem holders for consideration.

Participation in these and other public meetings and conferences required the preparation and distribution of technical publications, papers and reports. The CP-5 LSDP responded to the leadership of the SA and DOE-CH in the areas of participation, approval and archival of the products. Similarly, news releases and publicity activities were conducted in accordance with client direction.

8.4 Communications Approaches

Project status reporting was provided via several approaches. The project utilized the DOE Progress Tracking System through DOE-CH to provide formal dissemination of project status information on a monthly basis. Project activity was also disseminated in the CP-5 Monthly Work Report and the FETC DDFA Quarterly Progress Report, and monthly updates which was distributed to more than 200 interested parties. Additionally, the project participated in national STCG conference calls on a monthly basis. DOE reporting system requirements were met by the issuance of monthly CP-5 Activity Reports, which provided for internal dissemination of project information within DOE, as did participation by the SA in other DOE sponsored meetings and periodic management reviews.

Demonstration reporting was a core component of the communication effort of the CP-5 LSDP. Significant products included Technology Demonstration Summary Sheets and the Innovative Technology Summary Reports (ITSRs).

The Technology Demonstration Summary Sheets, 23 post-demonstration one-page summary level reports, were distributed through a DOE-CH targeted mailing, and included on the project Web Site. Normally available two weeks after each demonstration, the fact sheets were included in focused DOE-CH communications on CP-5 technology demonstration activities, distributed to the DOE Complex and U.S. Army Corps of Engineers. Other organizations representing DOE contractors, universities, national laboratories and scientific bodies, as well as the Community Leaders Network, were included in these mailings.

In addition to the Technology Demonstration Summary Sheets, 20 ITSRs were produced for the technology demonstrations. The transmittal of these ITSRs to FETC for publication and distribution was complemented by their inclusion on the CP-5 LSDP Web site.

In reference to the EM-40 Preferred Decommissioning Technology Guide, CP-5 technologies were presented by DOE-CH and FETC to EM-40 and the National Decommissioning Committee for consideration and inclusion in the Guide, following publishing of the ITSRs.

9.0 PROJECT SUMMARY

The implementation and success of the CP-5 LSDP was integral to the EM mission. Due to the significant number of D&D activities planned globally, including the DOE Complex, and the programmatic decisions which result from risk and funding prioritization, qualified environmental technologies must be available for field application in order to achieve the desired technical and economic benefit.

The benefits associated with the CP-5 LSDP experience primarily affected four groups of interested parties:

- Technical problem holders
- Technology developers/providers
- Stakeholders
- Strategic Alliance members

9.1 Benefits to Technical Problem Holders

The CP-5 LSDP demonstrated D&D technologies to benefit not only the ongoing project, but also broader DOE and commercial sector needs. The CP-5 LSDP provided a test bed for the selection, evaluation and demonstration of innovative environmental technologies, resulting in performance comparisons to existing baseline methods and technologies in the following areas:

- Technology Maturity
- Transportability
- Application to Real-Time D&D Project Needs
- Qualitative Performance
- Cost Savings/Cost Avoidance
- Technology Provider Interest

Considering the escalating constraints on program funding, prioritization of funding due to environmental risk and contractual agreements with stakeholders, the technical problem holder benefited from the demonstration of technologies deemed “field ready” and capable of achieving broad acceptance across the Complex. As such, the problem holder was assured of:

- Commercial quality application
- Equipment delivery to an ongoing D&D project
- Specified performance values including cost, radiological dose and waste measures
- Vendors interested in working with the problem holder to resolve technical issues.

Through an examination process, hundreds of technologies/applications were reduced to 32 technologies to be positively evaluated for demonstration. Post-evaluation contracting resulted in 23 technology demonstrations, which were accompanied by appropriate technical data reporting to assist the problem holder in decision-making.

9.2 Benefit to Technology Developers/Providers

The CP-5 LSDP provided vendors the opportunity to demonstrate technologies in an ongoing D&D project, thereby validating commercial application in a realistic environment. By virtue of contracting arrangements, most technology demonstrations were subsidized through cost-sharing provisions at CP-5. A significant additional benefit was the recognition of the technology and its potential for future commercial contracting within the DOE Complex and industry.

9.3 Benefits to Stakeholders

Generally, the demonstrated technologies provided information regarding technical and safety performance, and project cost and schedule. By using this information, the stakeholder can improve safety records for current or future projects, reduce future D&D costs and enable more accurate forecasting of project schedules.

9.4 Benefits to Member Organizations

The SA member organizations also benefited from participation in the CP-5 LSDP.

3M

Membership in the SA provided 3M several benefits relevant to commercial technology companies. These benefits include increased understanding of:

- D&D needs of nuclear facilities within the DOE Complex and, to some degree, the utility industry
- Selection criteria and requirements for D&D technology solutions
- Scheduling of D&D activities and factors influencing the schedule
- Organizations and programs in the D&D arena

Alliance activities associated with the technology selection and demonstration process contributed to this increased understanding. The teamwork among a broad cross-section of organizations in the program (commercial utilities, national labs, nuclear industry contractors, academia, technology companies and DOE) was also an important element. Ultimately, this sharing of information should help private industry better serve the customer in the identification, development and implementation of technologies and best practices for accomplishing D&D goals.

ComEd

As the largest nuclear utility in the United States, Commonwealth Edison (ComEd) shares with DOE-EM many of the future challenges of nuclear cleanup. The CP-5 LSDP has provided ComEd with the following benefits regarding site cleanup:

- Supported the development of a network of contacts for site cleanup and decommissioning operations to exchange ideas and lessons learned
- Provided a broad view of technologies to support the site cleanup and decommissioning efforts, including consistent performance and life cycle cost metrics
- "Springboard" for subsequent ComEd and DOE-EM relations
- Supported the development of a network of contacts for D&D related technologies
- Allowed opportunity to provide early input to technologies in "bench scale" development to allow fully deployable technologies to best meet user needs

Beyond the direct benefits noted above, ComEd's affiliation with this successful project has provided an opportunity for positive media coverage.

DE&S

Much like ComEd, Duke Energy has many challenges in the D&D area, both in short and long-term scenarios. Based on results from this project, Duke Energy has incorporated new technologies into its operation, maintenance and modification program. By participating in the CP-5 LSDP, DE&S gained valuable experience in the emerging D&D market, both in the commercial and government sectors. This experience included:

- New and emerging technologies for use in D&D projects
- Unique situations associated with D&D projects, including scheduling, procurement and contracting, safety and waste disposal
- Greater understanding of government procedures and processes
- Greater understanding of potential opportunities for future government work within the D&D arena

In addition to the D&D experience, DE&S gained leadership experience in the formation and execution of alliances. It is expected that the lessons learned and contacts made from this project will provide DE&S with the opportunity to be a major participant in future D&D and DOE projects.

Florida International University

The Hemispheric Center for Environmental Technology at Florida International University was established for the purpose of researching, developing and demonstrating innovative environmental technologies, and forging alliances that will support their implementation. To this end, the CP-5 LSDP has provided the following benefits:

- Exposure to a broad base of technologies
- Greater understanding of DOE needs
- Confirmation of the FIU technology assessments program
- Additional experience in the deployment of new technologies in radiological environments
- Greater understanding of DOE performance indicators for successful technology demonstrations
- Greater understanding of the drivers to take an innovative technology to the deployment stage
- Exposure to a larger client base

Experiences and lessons learned during the CP-5 LSDP have been incorporated in the technology demonstration process performed at FIU. These enhancements should help FIU provide better information about innovative technologies to D&D professionals and future LSDP's.

Argonne National Laboratory

As the host site for the LSDP, Argonne served a dual role in the execution of the project activities. From the problem holder perspective, the EM-40 D&D Program at the site received invaluable insight into the latest developments in D&D technologies which otherwise would have required extensive research and investigation. Having the D&D personnel responsible for the execution of the D&D activities at ANL directly observe, inspect and participate in the demonstrations provided an experience base which could not have otherwise been obtained.

From the perspective of a technology research and development (R&D) organization, ANL was able to work alongside members of many other diverse organizations and observe firsthand their viewpoint on how they perceive the needs in the area of D&D. This will provide a greatly enhanced focus on the directions to take in future R&D activities. In addition, from a technology provider perspective, ANL has gained an enhanced understanding of the obstacles and barriers to deploying new and innovative technologies. This understanding will enable ANL to assist DOE and utilities in determining when and how to deploy innovative technologies in the execution of their own projects. One of the more significant experiences gained from the CP-5 LSDP is the knowledge and understanding in the formation and management of complicated projects in a teaming or alliance environment.

The experience gained and lessons learned from this project will enable ANL to focus on a much broader perspective in solving national issues. This should lead to enhanced opportunities to use ANL's significant experience and unique capabilities in assisting government and industry in dealing with other issues of national importance.

ICF International

Membership in the SA provided ICF with valuable experience and insight into the emerging commercial and government D&D markets. This experience included:

- Benchmarking requirements as they relate to cross-technology comparisons and cost data required by the USACE in support of FETC.
- Insight into potential future applications of innovative technologies within the DOE Complex.
- Working with a broad cross-section of private, public and government organizations.
- Designing, coordinating, and maintaining the

SA Internet Website used for both external and internal communication.

- Providing coordination with the USACE and information for ITSR preparation.

The experience and lessons learned from the CP-5 LSDP will enable ICF to anticipate future needs of the D&D market and to become a significant participant in the D&D arena.

10.0 RECOMMENDATIONS AND LESSONS LEARNED

10.1 Deployment Opportunities

Consistent with the vision of the LSDP, the SA advanced the information exchange and, to a limited extent, transfer and application of successfully demonstrated technologies at CP-5 to the DOE Complex and private sites as discussed in Section 8, Communications. The following are examples of actual applications of technologies demonstrated for this project.

- Concrete Cleaning Inc., the service provider that demonstrated the Centrifugal Shot Blast technology at CP-5, was hired by Babcock &Wilcox for 30,000 ft^2, ¼-inch concrete removal at B&W's Parks Township plant in Pittsburgh.
- Bechtel also approached concrete Cleaning Inc. at the Nevada Test Site for concrete removal.
- X-Ray Fluorescence is routinely being used at ANL-E for hazardous materials analysis during characterization and facility assessments.
- SCM/SIMS has been deployed at ANL-E to support characterization of Building 301 Hot Cells.
- ISOCS is being used to provide in-situ spectroscopy information to support the planning of future D&D projects at ANL-E.
- ISOCS was used at ANL-E to assist in characterization of Building 301 Hot Cells.
- An alternate application of SCM/SIMS was identified and demonstrated as part of Hanford C Reactor LSDP.
- The Dual Arm Work Platform and the Rosie Remote Work System continued to be utilized at CP-5 for additional tasks after the completion of the demonstration.
- Pipe Explorer was used for characterization of below grade piping at ANL-E due to the success of the LSDP demonstration.
- Empore™ Selective Separation Systems have been used in prototype demonstrations at Savannah River to remove Cs from approximately 55,000 gallons of R-Basin water and at Paducah to remove Tc from approximately 22,000 gallons of groundwater.
- The Remote Control Demolition System was utilized at ANL-E for other than demonstration activities.

In addition, to aid in successful technology deployment to targeted DOE and private sites, the SA developed a list of potential opportunities (See Appendix E, Listing of Technology Deployment Opportunities).

Of the demonstrations at CP-5, the following technologies have been identified by ANL personnel as having a potential for possible future deployment at the ANL site.

- Remote Controlled Concrete Demolition System – Brokk BM 150
- Centrifugal Shot Blast
- Roto Peening Decontamination
- Surface Contamination Monitor
- Portable X-Ray Fluorescence Detector
- Radiation Imaging System/GammaCam™
- Pipe Crawler® or Pipe Explorer™ System
- Swing Free Crane
- Dual Arm Work Platform
- Rosie Remote Work System
- In-Situ Object Counting System
- Field Transportable Beta Counter

SA members conducted information searches via DOE Operations Offices, Site Technology Coordinating Groups' Web Sites and appropriate Nuclear Regulatory Commission (NRC) and Electric Power Research Institute (EPRI) Home Pages. Key information included technology description, technology developer/provider information, technology application, technology performance and cost information, potential deployment opportunity, problem description, and related problem information. The following potential deployment sites were identified during preliminary information searches:

- DOE-Operations/Field Offices
- Consumers Energy Big Rock Point Nuclear Power Plant
- ComEd Dresden 1 Nuclear Power Plant
- ComEd Zion Nuclear Power Plant
- Connecticut Yankee Nuclear Power Plant
- Maine Yankee Nuclear Power Plant

Given the schedule for completion of the CP-5 LSDP, full identification of deployment opportunities was not achieved. To the extent authorized, further information searches for other non-DOE and international needs should be conducted to identify additional deployment opportunities. Subsequent arrangements for site visits and extended technology deployment should result from that authorization. The following international potential deployment opportunities have been identified during preliminary discussions:

- Central and South America
- Former Soviet Union
- England
- Spain
- Belgium
- China
- Japan
- Germany

10.2 Large Scale Demonstration Lessons Learned

Strategic Alliance

During the course of the CP-5 LSDP, unanticipated problems, innovative ideas, and improvements were discovered. The SA compiled these concepts in hopes that future LSDPs may gain from CP-5 experiences. These Lessons Learned include:

- The organizational structure employed was very effective. The SA Board and TSC allowed a diverse selection of new technologies and methods to be quickly assessed and tested. This diversity produced better results than would be achieved with a traditional management contract for this type of project.
- Fixed price contracts for demonstrations leave no flexibility and are hard to execute.
- Costs for demonstrations should be accrued as soon as possible after completion in order to minimize possible "penalties" for uncosted carryover in the governmental system.
- A single communications mechanism is a valuable tool for dissemination of information. Communication goals, however, should be thoroughly identified and options explored at the beginning of the program to minimize the developmental costs.
- Small emerging companies have little experience in nuclear facilities' requirements. This leads to schedule delays and increased SA effort.
- Reliance on the estimated baseline does not provide the most reliable benchmark. Demonstrating the baseline technology alongside the emerging technology provides a better comparison. This comparative analysis of baseline technology and innovative technology would have to be a planning fundamental at project outset.
- In test plans, it is important to be very specific on DOE requirements for equipment brought by vendors to the facility (e.g., there is a difference between "HEPA filters" and "HEPA filters approved for use in nuclear facilities").
- A checklist should be used by Test Engineers to ensure that all required documentation is completed and available prior to the demonstration. This includes documentation from the vendor on HEPA filter DOP (or equivalent) testing and vendor training (e.g., respirator fit testing). This checklist should be included in the Test Plan, along with examples of information each document should provide.
- Vendors should visit the demonstration location at least two weeks prior to the

demonstration. This visit should include discussions between the Facility Supervisor and the vendor to ensure that all personnel involved understand what will happen during the demonstration and what is required of each party.
- The Technology Selection Committee (TSC) should fully understand all aspects of the baseline technologies (e.g., equipment used, support equipment required, depth of concrete removal estimated in baseline documents) prior to identifying innovative technologies for demonstration.
- The TSC must include D&D field people with a broad understanding of D&D performance factors.
- A strict set of guidelines proved very beneficial in the LSDP's approach to screening technologies for acceptability for demonstrations.
- The project communications function (media, presentations, formal reporting, and functions) should have dedicated public information support throughout the project to ensure consistency of project message.

Department of Energy
As part of this report, the DOE was asked to provide input to aid future government agencies in the area of LSDPs. The DOE Lessons Learned from a Federal Manager level for CP-5 include:

- Federal Managers should empower the IC Team to manage the LSDP without micro-management or undue control by the Federal Managers.
- The Federal Managers should act as technology marketers and promoters.
- A wide range of technical, managerial and administrative skills is needed to prevent workflow bottlenecking due to overwork of one or more key individuals.
- The U.S. Army Corps of Engineers needs to be more fully integrated into the project team.
- Three to four months of pre-project planning and negotiations is necessary for any LSDP.
- In some cases more than one demonstration of an innovative technology may be required to gauge its effectiveness in replacing the existing baseline.
- The TSC needs to implement a more widespread approach to identify potential innovative technologies, to ensure that as many applicable U.S. and foreign technologies as possible are considered.
- In addition to the DDFA, the crosscut areas of Robotics; Characterization, Monitoring and Sensors; and Efficient Separations should participate in identifying applicable technologies.
- The CP-5 LSDP demonstrated the ability of EM-40 and EM-50 to jointly work on a project with mutual and separate goals.
- Value would be gained by including the IC Team in expanded work on the LSDP, through subsequent projects at the same site or through decommissioning projects at other DOE sites.
- If practical, members of the IC Team on the CP-5 LSDP should be assigned to serve on the TSCs of future LSDPs, to transfer their experience to new projects.

11.0 REFERENCES AND PAPERS

References

CP-5 LSDP Management Plan, Rev. 0, March 1996.

Technology Selection and Demonstration Process, January 1996.

EM-40 Baseline Environmental Management Report.

Decontamination and Decommissioning National Needs Assessment.

Decommissioning Handbook, DOE/EM-0142P March 1994.

Oak Ridge National Laboratory Technology Logic Diagram.

Thomas Register of American Manufacturers.SM

Large Scale Demonstration Project Safety/Environmental Review Plan, PP-1.1-100, Rev. A-1, June 1996.

ITSR Draft Preparation Guidance Document.

CP-5 LSDP Communication Plan.

Web Site - http://www.strategic-alliance.org.

Papers

Aker, R. (ComEd), R. Rose (ANL-E), M. Ferrigan (DOE), *The CP-5 Large Scale Demonstration Project* Site Technology Coordinators Group Meeting Briefings, Oakland, CA April 1997.

Aker, R. (ComEd), *Strategic Alliance for Environmental Restoration - An Innovative Approach to Government and Decommissioning Technology*, American Power Conference Proceedings 1997.

Bhattacharyya, S. (ANL-E), *D&D Needs for Research and Test Reactors (Workshop)*, X-Change '97; December 1997.

Bhattacharyya, S., et. al. (ANL-E), *D&D Technology Demonstration on the CP-5 Reactor*, ANS Executive Conference on Decommissioning and Spent Fuel Disposal April 1997.

Bhattacharyya, S., et. al. (ANL-E), *Large Scale Demonstration of D&D Technologies*, 5th International Conference on Nuclear Engineering (ICONE-5) May 1997.

Black, D., Henley, D., Ditch, R., Seifert, L. (ANL-E), Haley, D., Noakes, M. (ORNL), *Deployment of Remote Dismantlement Systems at the CP-5 Reactor*, ANS 1st Topical Meeting on Decontamination, Decommissioning and Reutilization of Commercial and Government Facilities Sept. 7-12, 1997.

Black, D., Henley, D., Ditch, R., Seifert, L. (ANL-E), *Deployment of Remote Dismantlement Systems at the CP-5 Reactor*, ANS 7th Topical Meeting on Robotics and Remote Systems; April 27 - May 1, 1997.

Black, D., Henley, D., Ditch, R., Seifert, L., Yule, T. (ANL-E), *Status of Remote Dismantlement Needs at the CP-5 Reactor D&D Project*, Utilities/Manufacturers Robotic Users Group Conference; April 27 - May 1, 1997.

Bradley, T. (DE&S), Rose, R. (ANL-E), Ferrigan, M. (DOE), *The CP-5 Large Scale Demonstration Project*, Site Technology Coordinators Group Meeting Briefings (Rocky Flats, CO); April 1997.

Bradley, T. (DE&S), Rose, R. (ANL-E), Ferrigan, M. (DOE), *The CP-5 Large Scale Demonstration Project*, Site Technology Coordinators Group Meeting Briefings (INEEL, ID); April 1997.

Bradley, T. (DE&S), Rose, R. (ANL-E), Ferrigan, M. (DOE), *The CP-5 Large Scale Demonstration Project*, Site Technology Coordinators Group Meeting Briefings Hanford, WA April 1997.

Bradley, T., Eppler III, F. (DE&S), Aker, R. (ComEd), *Strategic Alliance for Environmental Restoration - an Innovative Approach to Government and Industry Cooperation for Decontamination and Decommissioning Technology Demonstration*, ANS Topical Meeting on Decommissioning, Decontamination and Reutilization of Commercial and Government Facilities Sept. 7-12, 1997.

Madaris, S. (FIU), Rose, R. (ANL-E), *The CP-5 Large Scale Demonstration Project*, Site Technology Coordinators Group Meeting Briefings (Oak Ridge, TN) April 1997.

Rose, R. (ANL-E), *D&D Needs at Laboratory Facilities (Workshop)*, X-Change '97 December 1997.

Rose, R. (ANL-E), *Deploying Innovative Technologies to Improve DOE D&D Project Baselines*, ANS 1st Topical Meeting on Decontamination, Decommissioning and Reutilization of Commercial & Government Facilities Sept. 7-12, 1997.

Rose, R. (ANL-E), *The Burgeoning Nuclear Reactor and Facility D&D Market - DOE Perspective*, 4th Annual Decommissioning Decision Makers Forum June 24-27, 1997.

Appendices

Appendix A
Technology Selection and Evaluation Sheet

STRATEGIC ALLIANCE FOR ENVIRONMENTAL RESTORATION

CP-5 LSDP TECHNOLOGY EVALUATION FORM

Technology Name:

File #:

Technology Provider:

Technology Description:

Technology Category:

Characterization ( ) Dismantlement ( ) Decontamination ( )
Worker Health & Safety ( ) Work Area Containment ( )

DOE/METC Funded Technology: Yes ( ) No ( )

Outside Technology: ( )

Technology Evaluation:
Accepted ( )
Not Accepted ( )
Reason:

Later Consideration: ( )

Baseline Technology by which this technology was evaluated:

I. Selection Criteria:

The following criteria must be satisfied before performing a detailed review:

State of Maturity: (Rank:)
Discussion:

Transportability to CP-5: (Rank:)
Discussion:.

Applicability to CP-5 Demonstration Needs: (Rank:)
Discussion:

Performance Indicators: (Rank:)
Discussion:

The following criteria are of high importance to ensure a technology demonstration would provide maximum benefit to the LSDP:

Application Across Complex: (Rank:)
Discussion:

Cost/Benefit (Complex-Wide): (Rank:)
Discussion:

Compatibility with CP-5 D&D Baseline Schedule: (Rank:)
Discussion:

The following criteria are of medium importance to ensure a technology demonstration would provide maximum benefit to the LSDP:

Improvement Over CP-5 Baseline: (Rank:)
Discussion:

Cost of CP-5 Demonstration: (Rank:)
Discussion:

Provider's Interest in Participating: (Rank:)
Discussion:

II. Contact Log Sheets

III. Specific Technology Information (Attachments)

Evaluator:

Appendix B
Listing of Technologies

Technology Category	Technology Title	Vendor Name	Telephone Number
Characterization	**Surface Contamination Monitor**	**Shonka Research Associates (SRA)**	(770) 509-7606
	Pipe Crawler	**Radiological Services**	(860) 443-4944
	Pipe Explorer	**Science & Engineering Associates**	(505) 884-2300
	Pipe Walker	Oceaneering, Inc.	(713) 488-9080
	In Situ Gamma Spectroscopy	Canberra Industries	(317) 298-7953
	Mobile Automated Characterization System (MACS)	**Oak Ridge National Laboratory**	(423) 576-4388
	Radiation Imaging System	**AIL Systems**	(516) 595-5595
	In-Situ Object Characterization	**Canberra Industries**	(317) 298-7953
	Portable X-Ray Fluorescence Surface and HEPA Detectors	**TN Spectrace**	(970) 493-2219
	Field-Transportable Beta Counter-Spectrometer	**Triangle Research**	(412) 941-0151
	Photogrammetry	Meier Associates	(509) 735-0159
	Long Range Alpha Detector (LRAD)	Los Alamos	(505) 471-3232
	Electret Ion Chamber	RAD Electric, Inc.	(800) 526-5482
	Nomad-Waste Characterization	EG&G Nuclear Instrument – ORTEC	(615) 483-2117
	Nomad-Facility Characterization	EG&G Nuclear Instrument – ORTEC	(615) 483-2117
	Hazardous Waste Monitor	Physical Sciences, Inc. (PSI)	(508) 689-0003
	Real-Time Floor Monitor	DOE Robotics Technology Program	(423) 576-4388
Worker Health & Safety	**Frham-Tex Cool Suit**	**Frham Safety Products**	(803) 366-5131
	NuFab Cool Suit	**G/O Corporation (Kappler USA)**	(800) 933-8501
	Tack-It Particulate Trapping Cloth	G/O Corporation	(800) 933-8501
	Thermal Wear Body Management System	Frham Safety Products	(803) 366-5131
	Thermalwear RiteCharge Warning System	Exothermal Technology Corporation	(407) 952-1200
	Breathable-Water Resistant Reusable Coveralls	Frham Safety Products	(803) 366-5131
	Advanced Worker Protection System	Oceaneering Space Systems, Inc.	(713) 488-9080
	Off-Site Laundry Service	Eastern Technologies, Inc.	(800) 467-0547
	Mobile Aqueous Borne Ozone Laundry Service for Reusable Clothing	Eastern Technologies, Inc.	(800) 467-0547
Worker Health & Safety (con't)	Permaselective Membrane & Carbon Absorption Clothing	Membrane Technology & Research	(415) 328-2228

Technology Category	Technology Title	Vendor Name	Telephone Number
	Heat Stress Eliminator Clothing	Kool N' Safe	(718) 853-8167
Decontamination	**Flashlamp**	**Polygon Industries**	(800) 765-9466
		Parsons Infrastructure & Technology Group	(423) 482-1434
		McDonnell-Douglas	(314) 232-0232
	Centrifugal Shot Blast	**Concrete Cleaning**	(509) 226-0315
		Nelco Manufacturing	(405) 478-3440
		LTC Americas, Inc.	(800) 822-2332
		Wheelabrator HPD	(707) 357-7330
	Rotary Peening with Captive Shot	**3M RotoPeen**	(612) 736-3655
		EDCO	(800) 638-3326
	Milling Decontamination	**Pentek**	(412) 262-0725
		LTC Americas, Inc.	(800) 822-2332
		Wheelabrator HPD	(708) 357-7330
	Remotely Operated Scabbler	**Pentek (Moose)**	(412) 262-0725
		SASE Company	(800) 552-2606
		Marinus Company	(201)567-8383
		Trelawny Pneumatic Tools	(800) 440-4854
		PRO S.P.E.	(281) 646-0024
	Carbon Dioxide Blasting	Oceaneering Technologies	(301) 249-3300
		TTI Engineering	(508) 660-3064
		Environmental Alternatives	(603) 256-6440
		ICE SOLV	(717) 838-0400
		Alpheaus Cleaning	(909) 944-0055
		Cold Jet	(513) 831-3211
		Maxwell Industries	(619) 696-8797
		Non-Destructive Cleaning	(508) 660-3064
		TOMCO	(404) 979-8000
		LITCO	(208) 526-1376
		Artic Blast	(708) 680-3064
	Ice Blasting	Applied Radiological Control	(800) 241-6575
		Ice Blast	(318) 261-0690
	Plastic Pellet Blasting	Barlett Services	(508) 746-6464
		Ice Blast	(318) 261-0690
		Surface Technology Systems	(330) 497-5905

Technology Category	Technology Title	Vendor Name	Telephone Number
Decontamination (con't)	**Soft Media Blasting**	Eastern Environmental Engineers	(617) 254-1157
		Cannon-Sline	(800) 729-4600
		Vulcan Painter	(205) 428-0556
		AEA O'Donnell	(412) 655-6083
		ICE SOLV	(718) 838-0400
		Aerojet	(423) 753-1252
	Grit Blasting	ABB Abrasive Blasting	(800) 255-7910
		Chamberlains	(609) 829-6444
		LTC Americas, Inc.	(800) 822-2332
		ICE SOLV	(717) 838-0400
		Wheelabrator HPD	(708) 357-7330
		Vacu-Blast, Ltd	UK
	Laser Decon	ANL/Lumonics Corp.	(630) 252-3254
		AMES Laboratory	(515) 294-4987
		LSP Technologies	(614) 424-5762
		F2 Associates	(505) 271-0260
	Chemical Decon	Pegasus International	(412) 295-0066
		B&W NESI	(804) 848-4615
		Corpex Technology	(423) 691-4877
		EET, Inc.	(713) 662-0727
		ABB-CE Nuclear Power	(203) 285-3833
		Decon Systems	(800) 473-3266
		Frametome USA	(703) 527-4747
		Radial Research	(718) 963-2233
		UNI-Chem	(216) 255-4070
		Vectra Technologies	(408) 281-6007
	Membrane Separation Cartridge	**3M**	(612) 733-8065
	Recyclable Media Blasting	Ecology and Environment	(208) 522 8133
	Non-Hazardous Coating Removal	Pegasus International	(412) 295 0066
	Superabsorbent Polymer	Chemdahl Corp.	
	Bio Surface Degradation	INEL	(208) 526-0948
	High-pressure Water	Various Companies	
	Ultra-high pressure Water	Various Companies	
	Electro-hydraulic Scabbling	Textron Services	(617) 381-4325

Technology Category	**Technology Title**	**Vendor Name**	**Telephone Number**
Decontamination (con't)	Microwave Decontamination	ORNL	(423) 574 0983
	Remote Operated Vehicle using CO2 Pellets	Oceaneering Technologies	(301) 249-3300
	Explosive Scabbling	Sandia National Laboratory	(505) 845-8989
	Electrokinetic Decontamination	Isotron	(504) 254-4624
	Soda Blasting	Armex (Church & Dwight Co.)	(800) 221-0453
		O'Brien and Gere Technical Assoc.	(423) 482-9430
		Schmidt Mfg.	(800) 231-2085
		Corrosion Specialties	(800) 535-4564
		MPR & Associates	(703) 519-0200
	EKOR Foam	Eurotech	(619) 551-6844
	Sponge Media	Sponge-jet	(800) 776-6435
	Diamond Concrete Cutter	Trentic, Inc.	(513) 677-0800
	Cement-Lock	ENDESCO	(847) 768-0522
	Rod Storage Liner Decontamination	FIU	(305) 348-1641
Dismantlement	**Swing-Reduced Crane Operation**	**DOE's Robotics Technology Program**	(432) 574-5691
	Dual Arm Work Platform	**DOE Robotics Technology Program**	(423) 576-4388
	Rosie Mobile Robot Work System	**RedZone Robotics**	(412) 765-3064
	Remote Controlled Concrete Demolition System	**Duane Equipment**	(888) 273-2511

Bold print indicates technologies demonstrated in the CP-5 LSDP.

Appendix C
Technology Demonstration Summary Sheets

http://www.fetc.doe.gov/dd/cp5/techdemo.htm

Appendix D
Listing of Innovative Technology Summary Reports

Advanced Recyclable Media System

- Surface Technology Systems Inc.
  Steven M. Pocock, President
  (330) 497-5905
  sts@cannet.com
- Advanced Recyclable Media Systems Inc.
  C. G. Gillooly, Vice President and General Manager
  (919) 941-0847
- Ecology & Environment Inc.
  Donald K. Vernon
  (208) 522-8133
  dvernon@ene.com

Centrifugal Shot Blast System

- Concrete Cleaning Inc.
  Mike Connacher
  (509) 226-0315
  conclsrs@aol.com

Dual Arm Work Platform Tele-operated Robotics System

- Robotics Technology Development Program, Oak Ridge National Laboratory
  Dennis C. Haley, D&D Robotics Coordinator
  (423) 576-4388
  h6y@ornl.gov

Empore™ Membrane Separation Technology

- 3M New Products Department
  Keith Hoffmann
  (612) 575-1795

Field Transportable Beta Spectrometer

- Triangle Research Ltd.
  Thomas L. Isenhour
  (412) 941-0151

FRHAM-TEX Cool SuitÔ

- FRHAM Safety Products
  Jim Brown
  (803) 366-5131

GammaCamÔ Radiation Imaging System

- AIL Systems Inc.
  Richard A. Migliaccio, GammaCam Engineering Manager
  (516) 595-5595
  migliaccio@ail.com

In-Situ Object Counting System (ISOCS)

- Canberra Industries Inc.
  Dale O. Elmore, Account Manager
  (317) 298-7953

Mobile Automated Characterization System

- Oak Ridge National Laboratory
  B. S. Richardson
  (423) 576-6820
  richardsonb@ornl.gov

NuFabÔ Anti-Contamination Suit

- Kappler USA
  Fernando Herrera
  (800) 750-3768

Pipe CrawlerÔ Internal Piping Characterization System

- Radiological Services Inc.
  Jim McCleer
  (860) 443-4944

Pipe ExplorerÔ Surveying System

- Science & Engineering Associates Inc.
  C. David Cremer
  (505) 884-2300
  cdcremer@seabase.com

D. T. Kendrick
(505) 884-2300
dtkendrick@seabase.com

Portable X-Ray Fluorescence Spectrometer

- TN Spectrace
  Anthony Harding, Applications Manager
  (970) 493-2219

Remote Controlled Concrete Demolition System

- Duane Equipment Corporation (the Brokk machine)
  Toby Duane
  (888) 273-2511

Remotely Operated Scabbling Technology

- Pentek Inc. Decontamination Products Division
  Linda Lukart-Ewanski
  (412) 262-0725
  pentekus@aol.com

Rosie: Mobile Teleoperated Robot Worksystem

- RedZone Robotics Inc.
  T. Denmeade
  (412) 765-3064
  tdenmeade@redzone.com
  Lou Conley
  (412) 765-3644
  lsdc@redzone.com

Rotary Peening with Captive Shot

- 3M Abrasive Systems Division
  Peter J. Fritz
  (612) 736-3655
  pjfritz@mmm.com
  Michael W. Lovejoy
  (612) 733-7181
- Pentek Inc.
  Craig S. Herbster
  (412) 262-0725
  pentekus@aol.com
- EDCO
  Paul Gorgol
  Leo Swan
  (301) 663-1600
- West Environmental Inc.
  Greg Butchko
  (800) 356-5748

ROTO PEEN Scaler and VAC-PAC System

- Pentek Inc., Decontamination Products Division
  Linda Lukart-Ewanski
  (412) 262-0725
  pentekus@aol.com

Surface Contamination Monitor and Survey Information Management System

- Shonka Research Associates Inc.
  Joseph J. Shonka, Research Director
  (770) 509-7606
  sra@crl.com

Swing-Reduced Crane Control System

- Oak Ridge National Laboratory
  Dennis C. Haley
  (423) 576-4388
  h6y@ornl.gov
- Convolve Inc.
  Neil C. Singer
  (212) 267-6775 ext. 205
- Whiting Services Inc.
  Edward R. Toretta
  (800) 789-9919

APPENDIX E
LISTING OF TECHNOLOGY DEPLOYMENT OPPORTUNITIES

Technology Description	Technology Provider Information	Technology Application(s)	Technology Performance and Cost Information	Potential Problem Holder(s)	Problem Description	Information Related to Problem
Empore Material Separation	3M	Contaminant Separation	See ITSR	DOE-AL/LANL PBS#AL/LANL/ER ADS#2001,2004,2005	Plume extraction and contaminant capture	Gilgosh, Mike 505-667-5794 #2 priority, est. $10M Sch. Comp. FY2005
Remote Controlled Concrete Decon	Pentek	Decontamination	See ITSR	DOE-AL/LANL PBS#AL/LANL/ER ADS#3001	Surface contamination	Gilgosh, Mike 505-667-5794 Est. $11M Sch. FY1998-2005
Concrete Shot Blast	Concrete Cleaning	Decontamination	See ITSR	DOE-AL/LANL PBS#AL/LANL/ER ADS#3001	Surface contamination	Gilgosh, Mike 505-667-5794 Est. $11M Sch. FY 1998-2005
RotoPeen Decon	3M/EDCO/West Environmental/ Pentek	Decontamination	See ITSR	DOE-AL/LANL PBS#AL/LANL/ER ADS#3001	Surface contamination	Gilgosh, Mike 505-667-5794 Est. $11M Sch. FY1998-2005
Empore Material Separation	3M	Contaminant Separation	See ITSR	DOE-AL/GJPA PBS#AL/GJO/ER ADS#ALUM2000, ALUM2023, ALGJ1002	Groundwater contamination	Cromwell, Vernon 970-248-7735 Est. $25M Sch. FY1999-2019
Swing-Free Crane	RTDP/ORNL	Metal size reduction	See ITSR	DOE-CH/ANL-E PBS#CH-ANLEDD ADS#1437,1441	Size reduction and segregation	Gabel, Drew 630-252-2213
Swing-Free Crane	RTDP/ORNL	Metal size reduction	See ITSR	DOE-CH/PPPL ADS#3100	Size reduction	Rule, Keith 609-243-2329 Sch. 12 months
Portable X-ray Fluorescence	TN Spectrace	Material assay	See ITSR	DOE-ID ADS#6354SF, 6351SF,6350SF	Non-destructive assay	Rivas, Dan 208-526-1212 BNFL Inst./Parjarito Scientific
Empore Membrane Separation	3M	Contaminant Separation	See ITSR	DOE-OH/FN PBS#4 AdRest RDS#R96A0014	Uranium contamination reduction in groundwater	Warner, Rod 513-648-3156 Baseline - Zeolite
Pipe Crawler Pipe Explorer	RSI SEA	Characterization	See ITSR	DOE-OR ADS#3201,3212,3301	Tank system characterization and content mapping	Robinson, Sharon 423-574-6779 Sch. FY1998-2002
Empore Membrane Separation	3M	Contaminant Separation	See ITSR	DOE-OR Need#WM-10	NPDES discharge metals	Crosley, Sladjana 423-574-1666
Remote Air Sampling	EML	Air Sampling	See ITSR	DOE-OR	Mercury emissions	Crosely, Sladjana 423-574-1666

Technology Description	Technology Provider Information	Technology Application(s)	Technology Performance and Cost Information	Potential Problem Holder(s)	Problem Description	Information Related to Problem
				Need #WM-13	from waste processing	(ADS4210 IncinOps; Trans. Vitrif sys; ADS 5201 Vortec Vitrif Cont Soils; ADA Technologies/SNL
Pipe Crawler Pipe Explorer Gamma Cam Portable XRF	RSI SEA AIL Systems TN Spectrace	Characterization	See ITSR	DOE-RF ID#RFDD01	Internals and piping	POC N/A
Portable XRF Gamma Cam	TN Spectrace AIL Systems	Characterization	See ITSR	DOE-RF ID#RFDD02	Surfaces, debris, rubble, equipment internals	POC N/A
Portable XRF	TN Spectrace	Characterization	See ITSR	DOE-RF ID#RFDD04	Excess property release	POC N/A
Remote Controlled Concrete Decon Shot Blasting	Pentek Concrete Cleaning		See ITSR	DOE-RF ID#RFDD09	Porous surfaces	POC N/A
Surface Contamination Monitor Portable XRF Gamma Cam	SRA TN Spectrace AIL Systems	Characterization	See ITSR	DOE-OH/Mound ADS#OHMB8005 RDS#R96E0023 WBS#5FHDSM0010	Facility surveys	Johnson, James (DOE)
Gamma Cam	AIL Systems	Characterization	See ITSR	DOE-OH/Mound ADS#OHMB8005 RDS#R96E0023 WBS#5FHDM0010	In-situ qualification	Johnson, James (DOE)
Portable XRF Gamma Cam	TN Spectrace AIL Systems	Characterization	See ITSR	DOE-RL RL-DD019-S	In-situ, remote NDE/NDA rad mapping methods	Goodenough, Jim 509-376-0893
Surface Contamination Monitor Portable XRF Gamma Cam	SRA TN Spectrace AIL Systems	Characterization	See ITSR	DOE-SRS ID#SR4002	Differentiation between contaminated and non-contamianted	Rimando, Rod 803-725-4118 Sch. FY1998-1999
Shot Blast Remote Controlled Concrete Decon	Concrete Cleaning Pentek	Decontamination	See ITSR	DOE-SRS ID#SR4004	Surface/subsurface contamination	Rimando, Rod 803-725-4118 Sch. FY1998-2003
Pipe Explorer Pipe Crawler	SEA RSI	Characterization	See ITSR	DOE-SRS ID#SR4005	Inaccessible areas, piping, drains, vent ducts	Rimando, Rod 803-725-4118 Sch. FY1998-1999
Swing-Free Crane	RTDP/ORNL	Dismantlement	See ITSR	DOE-SRS	Structural and	Rimando, Rod 803-725-4118

Technology Description	Technology Provider Information	Technology Application(s)	Technology Performance and Cost Information	Potential Problem Holder(s)	Problem Description	Information Related to Problem
				ID#SR4011	concrete facilities	

This report was prepared by:

Strategic Alliance for Environmental Restoration
Duke Engineering & Services
P.O. Box 1004
400 South Tryon Street
Charlotte, NC 28201-1004
Contact: Terry Bradley, Alliance Administrator
(704) 382-2766